CHAPTER 12

Indonesia: From Food Security to Market-Led Agricultural Growth

Keith O. Fuglie

1. INTRODUCTION

During the latter half of the twentieth 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). This transition from agricultural extensification to intensification was particularly noticeable in Asia, where population density is relatively high and land scarcity is acute. Indonesia is something of a special case, possessing both very densely populated, land-scarce agriculture on Java, and relatively land-abundant agriculture elsewhere on the large islands of Sumatra, Kalimantan, Sulawesi, and Papua. The country achieved considerable success in agriculture during the 1970s and 1980s through the diffusion of high-yielding varieties of food crops, although this source of growth appeared to stagnate by the early 1990s (Fuglie 2004). Meanwhile, land devoted to agriculture continued to expand, with virtually all new cropland coming from Indonesia's outer islands, and principally for tropical perennials like oil palm and cocoa. In this chapter, I examine the sources of agricultural growth in Indonesia over the 45 years from 1961 to 2006. I use a growth accounting method to examine how resource expansion, technologi-

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cal improvements, commodity diversification, and human capital contributed to growth in real agricultural output.

The approach used in this chapter builds on my earlier work (2004), which was the first to develop a Tornqvist-Thiel index of total factor productivity (TFP) for Indonesian agriculture. The present work expands commodity coverage to include cultured fisheries in addition to crops and livestock. Cultured fisheries, an increasingly important component of agriculture in many Asian countries, compete directly with crops and livestock for land, labor, feed, and other resources but have been largely ignored in assessments of agricultural productivity. In addition, this work includes improved data on agricultural cropland with more complete coverage of land planted to tropical perennials. Finally, the chapter develops a measure of labor force quality as a factor in production. In many developing countries in Asia, the rate of growth in the agricultural labor force has sharply declined or turned negative over the past several decades. However, labor force quality, in the form of higher literacy rates and universal primary education, has improved. Jamison and Lau (1982) compiled ample micro-level evidence to demonstrate the link between farmer education and agricultural productivity in developing countries; the present study accounts for the contribution of improvements in farmer education to productivity growth at the sector level.

The Tornqvist-Thiel indexes of output, input, and productivity are measures of changes in the real economy and avoid the index number bias arising from the use of fixed weights in input and output aggregation. Some previous studies of agricultural productivity in Indonesia have used agricultural gross domestic product (GDP) as a measure of output (Van der Eng 1996; Mundlak, Butzer, and Larson 2004), but GDP confounds quantity and price effects on output growth and thus may not reflect true changes in productivity. Other studies have estimated Malmquist TFP indexes for Indonesia using the Food and Agriculture Organization (FAO) output and input quantity data (Arnade 1998; Suhariyanto 2001; Coelli and Rao 2005). However, the FAO output measure is a Laspeyres index using a fixed set of international prices as weights to aggregate commodities and may result in biases if there are significant changes in relative prices or commodity mix over time (Fan and Zhang 2002). Moreover, the Malmquist index measure of agricultural TFP is sensitive to the dimensionality issue (e.g., the number of countries and input-output quantities included in the analysis) and may give implausible results (Lusigi and Thirtle 1997).

For this study I develop time series of output and input quantities and prices and use moving averages of revenue and cost shares to aggregate output and input quantities, respectively. Agricultural output is composed of 75 crop, animal, and fish commodities. The agricultural input index consists of 42 types of land, labor, capital, and intermediate inputs used in crop, livestock, and aquaculture production. The Tornqvist-Thiel TFP index is given by the ratio of aggregate output to input quantities, and thus TFP rises when the growth in the quantity of outputs exceeds the growth in the quantity of inputs. TFP is the residual component of growth after accounting for changes in factor inputs. It can be interpreted as a measure of the gain in efficiency with which inputs are used, including technological progress.

In the next section, I review the role of agriculture in Indonesia's economy and provide detail on changes in agricultural production and input use over time.

2. AGRICULTURE IN THE INDONESIAN ECONOMY

2.1. Agriculture's Contribution to GDP, Employment, and Trade

Indonesia is a Southeast Asian archipelago consisting of some 17,500 equatorial islands (6,000 inhabited) stretching in an east-west direction for over 5,000 kilometers. It has a land area of 1.83 million square kilometers supporting in 2005 a population of 221 million (the fourth-largest in the world), which was growing at about 1.4% per annum.

The extent of structural changes in the Indonesian economy between 1965 and 2005 is shown in Table 12.1. The population more than doubled over this period. Real GDP increased by about 10 times and real per capita income by about 480%. By 2005, Indonesia had a per capita income of $3,209 (2005 international dollars) and was classified by the World Bank as a lower-middle-income country. Large changes have occurred in the sectoral shares of GDP, with agriculture's share declining from 56% to 17%, accompanied by significant increases in the shares of the services sector (now the dominant sector with a 40% share in 2005); manufacturing (25%); and mining, oil, and gas (19%). Agriculture's share of total employment also declined, from nearly 70% in 1965 to 44% in 2005. It still remains the dominant sector of employment. While Indonesia's economy has become much more dependent on trade overall, agriculture's share in total merchandise exports fell from 57% to 20% between 1965 and 1975 but has fluctuated at around 20% since then.

Broad trends in the agricultural sector are shown in Table 12.2. Real agricultural GDP nearly tripled between 1961-65 and 2001-05 and averaged $95 bil-

Table 12.1. Agriculture in the Indonesian economy since 1965

Indicators	1965	1975	1985	1995	2000	2005
Population (millions)	105	133	163	193	206	221
Per capita income (2005 international dollars)	663	1,032	1,616	2,816	2,724	3,209
Gross domestic product (billions of 2005 international dollars)	69	137	263	543	562	708
Share of GDP (percent)						
Agriculture	56	30	23	17	17	17
Services	31	36	41	41	37	40
Manufacturing	8	10	16	24	25	25
Mining, Oil, and Gas	4	24	20	18	21	19
Share of employment (percent)						
Agriculture	69	62	55	44	45	44
Industry	7	8	13	18	18	18
Services	24	30	32	48	37	38
Trade as share of GDP (percent)	11	45	43	54	71	64
Ag share of total merchandise exports (percent)	57	20	21	27	16	18

Sources: WDI Online, except for agricultural exports. Agricultural exports include crop, animal, fish and seafood, wood and plywood products and are from the UN Comtrade Database.

lion (2005 international dollars) per year during 2001-05, making Indonesia the fifth-largest agricultural producer in the world (WDI Online). Food crops (particularly rice) constitute the largest component of agricultural output, but food crops' share of total output has gradually declined over time.

Rice production dominates the food-crop sector, and production increased four and a half times between 1961 and 2005, mainly as a result of yield increases. Adoption of modern varieties and fertilizers played an important role in securing higher yields. Rice remains the staple food, and national self-sufficiency carries great political significance. Estate crops, such as rubber, oil palm, sugarcane, and cacao, are becoming an increasingly important component of Indonesia's agricultural sector. Livestock and aquaculture production are also growing rapidly in response to the rising demand for animal protein, commensurate with rising per capita incomes.

According to the Indonesian Agricultural Census (done every 10 years since 1963), the number of farm households steadily increased between 1963 and 2003 in both Java and elsewhere, reaching a total of nearly 25 million households in 2003. According to census figures, average farm size has been decreasing in Indonesia, to about 0.4 hectares per household in Java and 1.3 hectares

Table 12.2. The structure of Indonesian agriculture, 1961-65 to 2001-05

Indicators	1961-65	1971-75	1981-85	1991-95	2001-05
	(annual average over period)				
Agricultural GDP (millions of 2005 international dollars)	35,987	42,311	55,271	83,567	95,268
Share of Ag GDP (percent)					
Food crops	64.8	59.9	61.8	55.8	51.1
Nonfood crops	17.4	17	15.7	16.6	14.9
Livestock	6.7	7.1	9.9	11.4	12.7
Fisheries	8	5.7	6.8	9.3	15
Forestry	3.1	10.3	5.8	6.7	6.3
Rice output (million tons of paddy)	12.4	21.2	35.8	47.5	52.5
Rice output per capita (kilograms milled rice)	97.6	110.5	154.6	165.0	157.6
Rice yield (tons per hectare)	1.8	2.5	3.8	4.4	4.5
Total crop land (million hectares)[a]	17.6	18.9	26.0	32.2	38.5
Java and Madura	9.0	8.8	7.0	7.1	7.0
Other islands	8.6	10.0	19.6	25.1	31.5
Number of farm households (millions)	12.2	14.4	19.5	21.7	24.9
Java and Madura	7.9	8.7	11.6	11.8	13.6
Other islands	4.3	5.7	7.9	9.9	11.3
Average size of farm[b] (hectares per farm)	1.1	1.0	1.0	0.8	0.8
Java and Madura	0.7	0.6	0.6	0.5	0.4
Other islands	1.7	1.5	1.6	1.2	1.3

Table 12.2. Continued

Indicators	1961-65	1971-75	1981-85	1991-95	2001-05
	(annual average over period)				
Agricultural wage (kilograms of rice per day)[c]	1.1	2.7	3.7	4.1	5.9
Agricultural exports % of Agricultural GDP	n.a.	n.a.	n.a.	24	37
Agricultural imports as % of Agricultural GDP	n.a.	n.a.	n.a.	11	14

Sources: Agricultural GDP, shares of Ag GDP, and agricultural trade are from BPS *Statistical Yearbook of Indonesia*. Rice output, livestock numbers, rice yield, and fertilizer use from FAOSTAT. Cropland, irrigated cropland, and agricultural wages are from Van der Eng 1996. Farm numbers and landholdings are from Agricultural Census for census years 1963, 1973, 1983, 1993 and 2003 as reported in Fuglie and Piggott 2006.

n.a. = not available.

[a]Includes land in annual (paddy, garden and upland crops) and perennial (estate) crops.

[b]Represents farm household landholdings and does not include land held by large estates.

[c]Represents wages of male workers on Java (rupiah per half-day of work divided by the farmgate price of rice).

per household outside of Java. The landholdings reported by the Agricultural Census include land in annual crops but exclude land in estate crops (although most estate crops are grown by smallholders), so these figures underestimate average agricultural landholdings per household.

Many household members that depend on agriculture do not own land of their own (or have only very small holdings) and work as laborers on other farms or corporate estates. Daily agricultural wages, measured in terms of the amount of rice afforded, rose more than six-fold between 1961-65 and 2001-05. Part of this rise in real wages can be attributed to Indonesia's success in raising its domestic rice supply, making rice more plentiful and cheap. Part of the rise in real agricultural wages is also due to growth in non-farm wages and a rising opportunity cost of labor.

Since the 1990s (earlier data are not available), trade in agricultural commodities has played an increasingly important role for Indonesia. The share of exports as a percentage of agricultural GDP rose from 24% in the early 1990s to 37% in 2001-05 while the value of agricultural imports rose from 11% to 14% of agricultural GDP (Table 12.2). Table 12.3 gives three snapshots (1976, 1996, and 2006) of the changing composition and value of major agricultural trade products. By 2006, oil palm products had replaced plywood and rubber as the dominant agricultural export. Fish, shrimp, cocoa, and coffee were other major export earners. For food and agricultural imports, in the 1960s Indonesia was the world's largest importer of rice, but by 2006, wheat, sugar, cotton, and feed grains (corn, soybeans, etc.) had become far more significant import items than rice. Indonesia enjoys a positive trade balance in food and agricultural products.

2.2. Changing Composition of Agricultural Outputs and Inputs

Table 12.4 describes the growth and composition of agricultural output and input use in Indonesia. Output figures are measured in terms of millions of tons of "rice equivalents" produced per year, averaged over a five-year period. To obtain rice equivalents, the output of each commodity is multiplied by its price relative to that year's price of (unmilled) rice and then aggregated across commodities (in other words, the price of paddy rice is a *numéraire* price). Thus, during 2001-05, Indonesian farmers produced a gross output of 143.6 million tons of rice equivalents annually, of which 52 million tons was rice itself. Oil palm was the second most important commodity, with gross production of palm oil and palm kernel oil together worth an equivalent of 10 million tons of rice. The importance of oil palm to the Indonesian agricultural sector is relatively new,

Table 12.3. The composition of Indonesia's agricultural trade

1976		1996		2006	
Major Ag Export Items	**Value (mil. US$)**	**Major Ag Export Items**	**Value (mil. US$)**	**Major Ag Export Items**	**Value (mil US$)**
Wood & plywood	787	Plywood	3,595	Palm & palm kernel oil	5,434
Natural rubber	532	Natural rubber	1,920	Natural rubber	4,322
Coffee	238	Palm & palm kernel oil	1,061	Plywood	1,507
Palm & palm kernel oil	136	Shrimp, fresh & frozen	851	Shrimp, fresh & frozen	1,087
Fish, fresh & frozen	124	Fish, fresh & frozen	493	Cocoa beans & butter	798
Tea	57	Coffee	595	Coffee	589
Pepper (Piper spp.)	47	Fruits & vegetables	376	Fish, fresh & frozen	490
Tobacco products	40	Cocoa beans & butter	345	Fruits & vegetables	472
Fruits & vegetables	18	Coconut oil & copra	340	Coconut oil & products	355
Cassava	11	Tobacco products	220	Tobacco products	340
		Tea	112	Tea	135

1976		1996		2006	
Major Ag Import Items	**Value (mil. US$)**	**Major Ag Import Items**	**Value (mil. US$)**	**Major Ag Import Items**	**Value (mil US$)**
Rice	450	Wheat & wheat flour	1,055	Wheat & wheat flour	959
Sugar	111	Cotton	980	Sugar	641
Cotton	84	Rice	766	Cotton	620
Wheat & wheat flour	75	Sugar	513	Fruits & vegetables	570
Cloves	42	Soybeans	252	Dairy products	569
Dairy products	39	Fruits & vegetables	250	Soybeans	300
Soybeans	20	Live animals	205	Corn	277
Tobacco products	13	Dairy products	194	Other animal feeds	236
Corn	9	Tobacco products	181	Tobacco products	191
		Corn	133	Rice	133
		Other animal feeds	126	Live animals	117

Source: UN Comtrade Database.

Table 12.4. Agricultural production and input use, 1961-65 to 2001-05

Production/inputs	1961-65	1971-75	1981-85	1991-95	2001-05
	(average annual quantity over period)				
Crop, animal & fish outputs, total (in million tons of rice equivalents)	28.42	54.57	81.53	117.45	143.60
Food crops, all	16.34	28.63	45.04	62.03	66.97
Rice, paddy	12.39	21.18	35.77	47.50	52.47
Cassava	1.47	2.52	2.51	3.91	2.54
Corn	1.14	1.99	2.56	4.02	7.13
Horticultural crops, all	3.15	6.08	8.22	12.64	19.30
Fruits, all	1.82	3.74	5.17	5.35	7.29
Vegetables, all	1.33	2.34	3.05	7.29	9.09
Nonfood crops, all	5.19	12.81	15.23	20.27	31.98
Oil palm	0.07	0.15	0.49	1.79	10.25
Coconut	1.25	5.35	4.78	5.51	6.52
Rubber	1.57	2.09	2.31	3.90	5.46
Sugarcane	0.40	1.82	2.87	3.92	2.85
Cocoa	0.00	0.01	0.07	0.47	1.84
Animal products, all	1.86	4.17	8.55	13.80	13.63
Meat	1.43	3.47	6.92	11.42	10.63
Milk and eggs	0.38	0.64	1.56	2.30	2.89
Fish products, all	1.88	2.60	4.48	8.71	11.72
Capture (marine & inland)	1.73	2.38	4.04	7.76	10.35
Aquaculture (marine & inland)	0.15	0.22	0.44	0.95	1.27

Table 12.4. Continued

Production/inputs	1961-65	1971-75	1981-85	1991-95	2001-05
	(average annual quantity over period)				
Agricultural inputs (in given units)					
Agricultural labor (million workers)	28.64	31.71	37.67	46.14	50.72
Cropland (million hectares)[a]	17.55	18.85	25.87	32.25	38.45
Irrigated cropland (percent)[b]	15.24	16.15	18.06	22.66	23.31
Animals (million head of cattle equivalents)[c]	14.00	13.59	18.41	30.99	33.15
Fertilizer (kilograms per hectare)	6.90	22.70	64.30	76.30	85.60
Tractor horsepower/1000 ha of cropland	2.91	5.89	7.42	20.34	35.11
Aquaculture area (thousand hectares)	293	292	328	503	728

Sources: Output quantities are from FAOSTAT. Output quantities are converted into "rice equivalents" using local wholesale prices from FAOSTAT, BPS *Statistical Yearbook of Indonesia*, and MOA. Agricultural labor, animal stocks, and fertilizer estimates are from FAOSTAT. Cropland, irrigated cropland, the number of tractors and aquaculture area are from BPS *Statistical Yearbook of Indonesia*. Tractors include 2-wheel and 4-wheel tractors.

[a]Includes land in annual (paddy, garden, and upland crops) and perennial (estate) crops.

[b]Represents percentage of cropland planted to annual crops receiving irrigation at least part of the year.

[c]Sum of cattle, buffalo, horses, small ruminants, pigs, and poultry aggregated using Hayami and Ruttan (1985) weights.

having increased by a factor of six just over the last decade. Cocoa, horticultural crops, animal products, and aquaculture were other fast-growing components of the agricultural sector. Rice production grew rapidly during the green revolution decades of the 1970s and 1980s, but growth in rice and other food crop production slowed after 1990.

In the latter half of the twentieth century, Indonesia added significant amounts of land, labor, and other inputs to agriculture (Table 12.4). Cropland expanded by an average of 1.4% per year during 1961-2005 and was still growing by more than 1% per year in the 2001-05. Figure 12.1 shows trends in cropland for densely populated Java and for other islands since 1961. While Java constitutes only 7% of Indonesia's land area, it holds about 60% of the nation's population and in 2000 had a population density of 856 persons/km^2 (BPS, *Statistical Yearbook of Indonesia*). Virtually all of the expansion of cropland since 1961 has occurred outside of Java, especially on the islands of Kalimantan, Sumatra, and Sulawesi. Nationally, agricultural cropland expanded to 38 million hectares by 2005. Irrigation had been extended to 4.8 million hectares and covered about 60% of the wetland rice (*sawah*) area, or about 23% of total cropland. Land resources devoted to aquaculture (brackish and freshwater ponds) grew

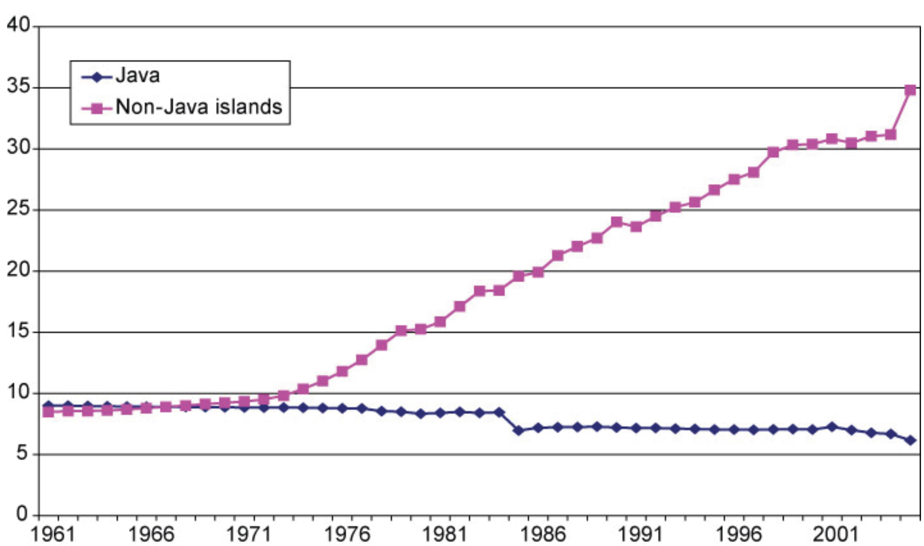

Figure 12.1. Agricultural cropland in Indonesia (million hectares)

Source: BPS *Statistical Yearbook of Indonesia*, supplemented by data from Van der Eng (1996) and MOA.

from 0.3 million hectares to 0.7 million hectares between 1961-65 and 2001-05, with expansion of ponds accelerating over time. But the largest increase in cropland was for estate crops. The new estimates of area planted (including area in immature trees) show that estate cropland grew from 4.6 million hectares in the early 1960s to over 18 million hectares by 2006. By the late 1990s, oil palm had replaced rubber and coconut as the dominant estate crop and by 2006 accounted for about one-third of the total area in estate crops. About 14 million hectares out of a total of 18 million hectares in estate crops were held by smallholders with 1-2 hectares of estates and the rest by large private and state-owned plantation companies (MOA).

FAO reports that the number of persons employed in agriculture in Indonesia grew from 28 million to 51 million persons between 1961-65 and 2001-05 and was still growing by about 0.6% per year in 2001-05. However, many of these persons only work part-time in farming, earning a large share of their household income from non-farm activities. In densely populated Java, time spent in farming per agricultural worker probably declined over time, as census data has shown that the share of non-farm income in the total income of farm households has risen (Booth 2002). However, outside of Java, area in crops expanded more rapidly than the agricultural labor force so that area farmed per worker rose (Van der Eng 1996). In these regions, average time spent farming per worker may have increased, as mechanization levels remained very low. This is where most of the expansion in estate crop production occurred, and, unlike annual crops for which labor demand tends to be seasonal, labor required in tree-crop production is often more evenly spaced throughout the year. Oil palm bunches, for example, ripen continuously throughout the year and need to be selected and picked manually when ripe. It is difficult to say how per capita labor allocated to agriculture may have trended nationally, but it is worth noting that cropland per capita grew, from about 0.8 ha per person in 1960-65 to 1.1 ha per person in 2000-05 (Table 12.2).

Use of manufactured inputs used in agriculture, such as fertilizer, machinery, and animal feed, grew rapidly in the 1970s and 1980s but from almost negligible initial levels. Fertilizer use increased by 11% per year during 1961-1980, when high-yielding, fertilizer-responsive varieties of rice were widely adopted and the government introduced subsidies for fertilizers and pesticides. The level of fertilizer subsidy was as much as 50% from the mid-1970s to the mid-1980s but then gradually declined and ended in 1999 (although subsequently it was reintroduced but at a relatively modest level). Average fertilizer application reached 105 kg/ha of harvested area by 2005 but was still low by international or even Asian standards (Mundlak, Butzer, and Larson 2004). Adoption of farm machinery accelerated after 1970, first for mechanical rice millers that replaced hand pounding and more recently for two-wheel walking tractors that are beginning to replace draft animals in tillage operations. However, the ratio of tractor horsepower to workers remained very low compared with other Asian countries like China and India. By 2002, there was only about 1 tractor in use per 250 farm households.

3. YIELD TRENDS

In this section, I examine yield trends of agricultural land and labor. I first describe resource productivity trends for the sector as a whole and compare land and labor productivity trajectories between densely populated Java and other land-abundant regions of the country. I then show yield trends for specific agricultural commodities over the 1961-2007 period, starting with food and horticultural crops. Nearly all of these crops are produced by farm families, most possessing less than two hectares of land. Next, I examine yield trends in estate crops and compare productivity levels between large plantations and smallholder estates. There is a wide range in the scale of estate holdings in Indonesia, from smallholders operating 1-2 hectares to large corporate and state farms that may operate over 100,000 hectares. The relation between scale and productivity in estate crop production has received considerable policy attention in Indonesia, as smallholder tree-crop producers are thought to have generally lagged behind large estates in technology, management, and yield (Barlow and Tomich 1991; Hartemink 2005). I compare yield and yield trends between smallholders and large estates for those commodities for which both have significant shares in production. Finally, I examine some productivity indicators for animal and cultured fish production, namely, meat and milk produced per head of stock and fish per hectare of area in ponds.

3.1. Agricultural Land and Labor Productivity

Hayami and Ruttan (1985) hypothesized that countries with different resource endowments would follow different paths of technological development in agriculture. Population-dense (land-scarce) Asian countries, they argued, would develop and adopt land-saving technologies like high-yielding crop varieties and fertilizers. Indonesia represents something of a special case, possessing both densely populated agricultural areas, mainly in Java, and large but sparsely populated regions in other islands. Figure 12.2 plots the trends in land and labor productivity (averaged over five-year intervals) for each decade from 1961-65 through 2001-05. Plotted along the vertical axis is average output per hectare of cropland while the horizontal axis shows output per worker. The plots show the productivity trajectories for Java and non-Java regions of the country as well as the average for the country as a whole. In Java, land and labor productivity both grew substantially between the 1960s and 2001-05, as farmers intensified production, first through green revolution rice technologies and later by shifting more resources into higher-valued horticultural, livestock, and aquaculture commodities. Land per worker fell over time as the agricultural population grew while agricultural land fell. On other islands (Sumatra, Kalimantan, and Sulawesi, primarily), expansion of land area was the primary source of growth, and land productivity hardly improved. Labor productivity increased, however, as the average cropland per worker rose. While the average productivity of farmland has been much higher on Java, the increasing area

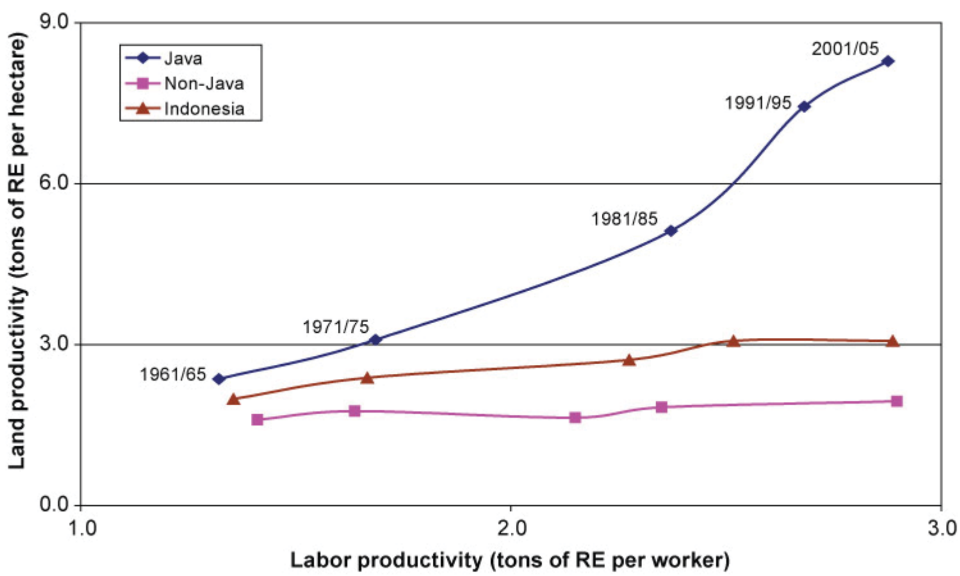

Figure 12.2. Land and labor production in Java and non-Java regions of Indonesia

Source: Author's estimates using data from BPS *Statistical Yearbook of Indonesia*, MOA and Van der Eng (1996).
Notes: RE = rice-equivalent value of total crop and livestock production. The points are the average annual values over the indicated five-year period.

worked per farm on non-Java islands served to close the gap in labor productivity between these regions.

3.2. Food Crops

Yield trends for rice and other food and horticultural crops are given in Table 12.5. Rice, which alone accounts for about half of the gross value of agricultural output, benefited considerably from dissemination of high-yielding green revolution varieties in the 1970s and 1980s. There are about 8 million ha of wetland paddy area (4.5 million ha of which are irrigated) and 1 million ha of upland (unterraced) rice area in Indonesia. Much of the irrigated area is double-cropped, and total rice area harvested reached 11 million ha by 2005. Between the 1960s and 1980s, average yield per hectare of harvested area doubled from 1.9 tons/ha to 4.0 tons/ha. But yield growth slowed markedly in the 1990s, and rising to only 4.5 tons/ha by 2001-07. Growth in yield accounted for more than two-thirds of the total growth in rice production over most of the 1961-2007 period, with growth in area harvested accounting for the other third. Presently, the government of Indonesia is cooperating with a number of private breeding companies to develop hybrid rice varieties in an effort to raise yield.

Corn and cassava are the second most important food crops in Indonesia and are staple foods in certain regions of the country. They are also important co-staples with rice for poor households as well as used for animal feed and starch production. These crops (and other secondary food crops) are mostly grown on rain-fed cropland. Corn yield started to increase in the 1970s and has experienced steady growth, doubling from 1.2 tons/ha in 1971-80 to 3.3 tons/ha in 2001-07 as improved hybrid varieties became widely adopted (Table 12.5). Cassava yield has also grown, although yield growth has been uneven over time. Some improved varieties have been developed but adoption rates remain low, restricted mainly to Lampung Province in Sumatra where cassava is used by agro-processors to produce commercial starch and animal feed. Area planted to cassava has trended downward, so that production has grown at a slower rate than yield.

There has been virtually no yield growth in soybeans and mungbeans since the 1960s, with yield of both crops averaging around 1 ton/ha. Groundnuts, on the other hand, have seen some modest yield growth of about 1% per year, to rise from 1.2 tons/ha in the 1960s to 2.0 tons/ha in 2001-07. These crops are often grown in rain-fed paddy fields during the dry season following the rice harvest or in upland fields.

Table 12.5. Yield trends for rice, secondary food crops, and horticultural crops

Commodity	1961-70	1971-80	1981-90	1991-00	2001-07
Rice			(average over period)		
Average yield (mt/ha)	1.9	2.7	4.0	4.3	4.5
Annual yield growth (%/year)	3.3	3.3	2.7	0.2	0.9
Share of production growth due to yield	64	76	63	16	67
Corn					
Average yield (mt/ha)	1.0	1.2	1.8	2.4	3.3
Annual yield growth (%/year)	0.4	4.2	3.8	2.6	3.7
Share of production growth due to yield	17	121	73	72	106
Cassava					
Average yield (mt/ha)	7.5	8.7	11.0	12.1	15.0
Annual yield growth (%/year)	-0.1	2.6	2.2	0.4	3.7
Share of production growth due to yield	--	96	152	231	131
Soybeans					
Average yield (mt/ha)	0.7	0.8	1.0	1.2	1.3
Annual yield growth (%/year)	0.5	2.2	2.2	1.0	0.7
Share of production growth due to yield	32	81	27	--	--
Groundnuts					
Average yield (mt/ha)	1.2	1.4	1.7	1.8	2.0
Annual yield growth (%/year)	0.8	2.9	0.6	0.7	1.5
Share of production growth due to yield	63	51	19	60	81
Mungbeans					
Average yield (mt/ha)	1.1	1.0	1.3	1.2	1.0
Annual yield growth (%/year)	0.7	-3.2	4.8	-4.8	2.7
Share of production growth due to yield	--	--	76	--	191
Vegetables					
Average yield (mt/ha)	3.8	4.3	4.7	7.6	8.9
Annual yield growth (%/year)	0.6	1.0	3.9	2.6	1.3
Share of production growth due to yield	16	--	62	61	49

Table 12.5. Continued

Commodity	1961-70	1971-80	1981-90	1991-00	2001-07
Fruit crops			(average over period)		
Average yield (mt/ha)	1.7	1.8	1.9	2.4	3.6
Annual yield growth (%/year)	3.4	-1.1	1.1	1.9	7.1
Share of production growth due to yield	69	--	32	59	79

Source: FAOSTAT.

Note: Mungbeans are classified as "Beans, dry" in FAOSTAT.

Vegetable and fruit production has grown rapidly in Indonesia, especially since the 1980s. Growth in per capita income has increased the demand for high-valued fruits and vegetables. Principal vegetable crops include chilies, shallots, potatoes, and cabbages. Temperate zone vegetables like potatoes and cabbages are grown in cool tropical highlands. Yield improved following adoption of improved varieties, better-quality seed, fertilizers, and pesticides. Principal fruit crops include bananas, mangoes, oranges, and papayas. Typically, farmers grow many varieties of these fruits for home consumption and market sales. Average yield of fruits has improved somewhat as farmers have increased commercial fruit production.

3.3. Estate Crops

Estate crops have played an important role in the Indonesia archipelago since the sixteenth century, when the country was the sole source of global supply of exotic spices like nutmeg, cloves, and pepper. In the nineteenth century, Indonesia emerged as a leading exporter of sugar and coffee. In the early twentieth century, colonial and smallholder estates responded to the raw material demands of the emerging global auto industry by greatly expanding area in rubber production, and by the 1920s rubber had become the dominant export crop of Indonesia (Kano 2008). Export-oriented estate production suffered a major reversal when commodity prices collapsed during the Great Depression. Production was further disrupted by World War II and the War of Independence (1945-49), although it began a modest recovery in the 1950s until foreign estates were nationalized in 1957. In the 1970s the government of Indonesia initiated major programs to expand estate crop production, especially in sparsely populated regions of Sumatra, Kalimantan, Sulawesi and Papua. A "transmigration" program resettled farm families from densely populated Java, and elsewhere to these regions. A "nucleus-estate" program provided corporations with subsidized capital and long-term leases to public lands for estate crop production, on condition that these companies provide technical and marketing services to smallholder estates surrounding the company plantations. Nucleus estate schemes were especially important for the oil palm industry, which greatly expanded after 1980. By 1999, oil palm became the dominant estate crop, surpassing both rubber and coconut in total area planted. The government of Indonesia estimates that more than 7.2 million ha were planted to oil palm in 2009, accounting for about one-third of the total area in estate crops. Cocoa also has also undergone a major expansion since the 1980s, with area planted rising from less than 40,000 ha in 1980 to an estimated 1.47 million ha in 2009.

While smallholders dominate production of a number of estate crops, both smallholders and large private and state-owned companies participate in the production of oil palm, rubber, cocoa, sugarcane, and tea. Table 12.6 shows the percentages of total area planted by smallholders for these commodities and compares the average yields obtained on smallholder farms and large estates over time. Smallholders have dominated rubber production (with over 80% of total area) since before the 1960s and account for nearly all of the growth in cocoa area since 1980. Large estates (mostly privately owned) account for most of the area in oil palm, but the role of smallholder producers has steadily risen. By 2001-07, smallholders accounted for 40% of the total area planted to oil palm in Indonesia. State-owned estates play a major role in tea and sugarcane production, and shares of smallholders in these crops have fluctuated over time but show no pronounced trend.

While family-owned or managed farms are the dominant (and most efficient) form of farm structure, Binswanger and McIntire (1987) identify conditions under which large corporate estates may achieve economies in agricultural production. Large estates can usually access lower-cost capital and thus will have some cost advantages over smallholders (at least initially) in crops for which a significant capital investment with a long payoff period is required, such as with tree crops. Large estates may also have advantages with certain crops that require close coordination between harvesting and processing due to rapid perishability of the harvest. Crops that fit this category include oil palm fruit, sugarcane, and tea leaves. However, large estates also have disadvantages, particularly in the management and oversight of labor. Hired labor is likely to have weaker incentives than family labor to perform myriad farm tasks in a timely and efficient manner.

Table 12.6 indicates that while smallholders initially had smaller yields than large estates, the yield gaps have diminished over time. By 2001-07, average smallholder yields in oil palm, sugarcane, and cocoa approached or exceeded average yields on large estates. Only in rubber and tea production did large estates obtain consistently better yields than smallholders. However, the lower average yield of smallholder rubber growers partly reflects lower tree density on these farms rather than yield per tree. Unlike large estates, which emphasize monocropping, smallholder estates typically use a mixed cropping system in which rubber trees are planted with lower density to accommodate other species of crops on the same land (Tomich et al. 2001).

Table 12.6. Area and yield of large and small estate crop producers

Commodity	1971-80	1981-90	1991-00	2001-07
Oil palm		(average over period)		
Total area planted (thousand ha)	206	646	2,501	5,472
Share of area planted by smallholder estates	0	16	30	40
Yield of smallholder estates (kg/ha planted)	184	522	1,455	1,868
Yield of large estates (kg/ha planted)	2,053	2,531	2,220	2,171
Rubber				
Total area planted (thousand ha)	2,336	2,785	3,440	3,310
Share of area planted by smallholder estates	80	83	85	85
Yield of smallholder estates (tons/ha planted)	322	324	391	574
Yield of large estates (tons/ha planted)	561	702	717	825
Cocoa				
Total area planted (thousand ha)	22	152	585	1,049
Share of area planted by smallholder estates	33	55	74	90
Yield of smallholder estates (tons/ha planted)	135	222	563	664
Yield of large estates (tons/ha planted)	239	467	453	606
Sugarcane				
Total area planted (thousand ha)	215	352	397	361
Share of area planted by smallholder estates	48	74	60	54
Yield of smallholder estates (tons/ha planted)	3,482	5,659	5,294	5,280
Yield of large estates (tons/ha planted)	8,235	4,629	4,706	5,764
Tea				
Total area planted (thousand ha)	102	120	146	143
Share of area planted by smallholder estates	35	41	41	44
Yield of smallholder estates (tons/ha planted)	430	516	553	649
Yield of large estates (tons/ha planted)	935	1,410	1,441	1,580

Table 12.6. Continued

Commodity	1971-80	1981-90	1991-00	2001-07
Estate crops with over 95% of area planted by smallholders		(average over period)		
Coconut				
Total area planted (thousand ha)	2,271	3,085	3,669	3,849
Average yield (kg copra/ha)	641	628	741	818
Coffee				
Total area planted (thousand ha)	353	623	868	1,302
Average yield (kg/ha)	567	560	541	497
Clove				
Total area planted (thousand ha)	243	640	509	442
Average yield (kg/ha)	102	80	136	177
Tobacco				
Total area planted (thousand ha)	177	208	202	228
Average yield (kg/ha)	506	561	712	800
Pepper				
Total area planted (thousand ha)	55	93	130	196
Average yield (kg/ha)	603	548	459	421

Source: MOA.

3.4. Livestock and Fisheries

Table 12.7 shows production and yield trends for meat, milk, and aquaculture in Indonesia. Rising per capita income has increased demand for these products domestically while shrimp is an important export item. Meat production doubled between the 1970s and 1980s, and more than doubled again by 2001-06 to more than 2.2 million tons per year. The total stock of animals, measured in "cattle equivalents" averaged 34 million head in 2001-06.[1] The fastest-growing component of meat production has been for poultry. Advances in production efficiency, particularly in commercial broiler production, have steadily increased annual meat production per head of cattle-equivalent animal from 40 kg/head in the 1970s to 66 kg/head in 2001-06.

Dairy is a relatively small industry in Indonesia but has grown over time, especially between the 1970s and 1990s. Improved breeds, feed, and veterinary care has helped raise milk output per cow. During 2001-06, each cow produced on average 1,471 liters of milk per year, more than double the average milk yield in the 1970s.

Table 12.7. Production and yield trends in meat, milk, and fish production

Commodity	1971-80	1981-90	1991-00	2001-06
Meat	(annual average over period)			
Production (thousand tons)	551	1,068	1,803	2,233
Animal stock (million cattle equivalents)	14	22	31	34
Yield (kg per head of stock)	40	50	58	66
Milk				
Production (million liters)	53	209	403	536
Milking cows (thousand head)	85	216	331	364
Yield (liters per cow)	627	967	1,215	1,471
Cultured fisheries (brackish & freshwater)				
Production (thousand tons)	161	344	648	1,062
Area in ponds, cages, and paddy fields (thousand ha)	267	370	548	736
Yield (kg per hectare)	602	930	1,181	1,442
Capture fisheries (marine & inland)				
Production (thousand tons)	1,489	2,502	4,210	5,645

Sources: Meat and milk statistics from FAOSTAT. Fisheries statistics from BPS *Statistical Yearbook of Indonesia*.

[1] "Cattle equivalents" are estimated by weighting various species of livestock and poultry by their size relative to cattle. Weights are from Hayami and Ruttan (1985) and are as follows: cattle = 1.00, buffalo and horses = 1.25, pigs = 0.25, small ruminants = 0.13, and poultry = 0.0125.

Fish production is an important industry in the Indonesian archipelago. Although marine and inland capture fisheries account for most fish production, output from capture fisheries has stagnated and growth in fish production now comes almost entirely from cultured fisheries. By 2001-06, farmers had developed over 700,000 hectares of ponds, which produced more than 1 million tons of fish and shrimp, or about 16% of total fisheries output in Indonesia (BPS, *Statistical Yearbook of Indonesia*). Output per hectare of land in ponds also rose over time, because of adoption of technologies that allowed shrimp and other species to be farmed in higher densities. Since 2001, white shrimp (*Penaeus vannamei*) have largely replaced black tiger prawns (*P. monoden*) in Indonesia and other Asian fisheries as a result of advances in white shrimp pathogen-free propagation and breeding methods (Shaun Moss, Oceanic Institute, Hawaii Pacific University, personal communication 2008).

4. TOTAL FACTOR PRODUCTIVITY OF INDONESIAN AGRICULTURE

In a multi-output, multi-input enterprise like agriculture, land and labor productivity trends like those described in the previous section give an imperfect measure of technical change, since they are also influenced by how intensively other inputs are used in production. In this section, I develop a measure of total factor productivity for the agricultural sector as a whole. Changes in TFP reflect an improvement in efficiency with which all inputs are employed and provide a more robust measure of technical change in the sector.

4.1. Methodology

For assessing changes in TFP, I construct Tornqvist-Thiel indexes of aggregate output and input quantities, and then take the ratio of these as an index of TFP. In other words, TFP measures the average product of all inputs. Let the total quantity of outputs be given by Y and the total quantity inputs by X. Then TFP is simply

$$TFP = Y/X. \tag{1}$$

Changes in TFP are found by comparing the rate of change in total output with the rate of change in total input. Expressed as logarithms, changes in equation (1) over time can be written as

$$\frac{d\ln(TFP)}{dt} = \frac{d\ln(Y)}{dt} - \frac{d\ln(X)}{dt}. \tag{2}$$

Since X and Y are composed of multiple inputs and outputs, an aggregation procedure is needed to construct the index. Solow (1957) showed that under the assumptions that (i) producers maximize profits and (ii) markets are in long-run competitive equilibrium, then equation (2) can be written as

$$\ln\left(\frac{TFP_t}{TFP_{t-1}}\right) = \sum_i R_i \ln\left(\frac{Y_{i,t}}{Y_{i,t-1}}\right) - \sum_j S_j \ln\left(\frac{X_{j,t}}{X_{j,t-1}}\right) \tag{3}$$

where R_i is the revenue share of the ith output and S_j is the cost-share of the jth input. Output growth is estimated by summing over the output growth rates for each commodity after multiplying each by its revenue share. Similarly, input growth is found by summing the growth rate of each input, weighting each by its cost share. TFP growth is just the difference between the growth in aggregate output and aggregate input. A discrete time approximation of the Divisia index given in equation (3) is the Tornqvist-Thiel productivity index:

$$\ln\left(\frac{TFP_t}{TFP_{t-1}}\right) = \sum_i \frac{\left(R_{i,t} + R_{i,t-1}\right)}{2} \ln\left(\frac{Y_{i,t}}{Y_{i,t-1}}\right) - \sum_j \frac{\left(S_{j,t} + S_{j,t-1}\right)}{2} \ln\left(\frac{X_{j,t}}{X_{j,t-1}}\right). \tag{4}$$

Denny and Fuss (1983) showed that the Tornqvist-Thiel TFP index in equation (4) can be derived from a translog production function that exhibits Hicks-neutral technical change. Because the translog is a flexible function form, the Tornqvist-Thiel index provides a superior measure of productivity change than alternatives that assume a more restrictive production relationship.

A further modification of the index construction is to account for changes in labor quality over time. I construct a labor quality index based on the average schooling level achievement of the male and female agricultural labor force. Specifically, let $L_t^* = \lambda_t L_t$, where L_t^* is the observed number of work days in year t, λ_t is a quality indictor of educational achievement, and L_t is the labor force measured in constant-quality units. Using a Mincerian-type earnings function, the labor force quality indicator is specified as

$$\lambda_t = \exp\left(\alpha s_t\right) \tag{5}$$

where s_t is the average educational level of the farm labor force and α is the percent increase in labor productivity due to education (i.e., $d\ln(\lambda_t)/ds_t = \alpha$). This allows us to decompose the effects of changes in labor quantity and quality on agricultural growth over time. The Mincerian interpretation of equation (5) is that *s* is the average number of years of schooling and α is the rate of return to an additional year of schooling (Psacharopoulos and Patrinos 2004).

4.2. Data

Recent improvements in the quality and coverage of data on agricultural production and input use have facilitated measurement of agricultural productivity change in Indonesia. Van der Eng (1996) developed long-term series (1880-1992) for outputs and prices of major crop and livestock commodities as well as land and labor inputs. For the post-1960 years, Van der Eng's (1996) data, which are based on Indonesian government sources, provide superior estimates of cropland for Indonesia than FAO estimates (which substantially underestimate historical land-use changes for this country). I recently (Fuglie 2010) further improved on these series by developing a more complete measure of area in perennial crops since 1961.

For agricultural output, I use FAO data to measure annual gross production of 55 crop commodities and 19 livestock commodities since 1961.[2] I also include output from cultured fisheries (which include brackish and freshwater ponds, cages, and paddy fields) using estimates from the *Statistical Yearbook of Indonesia* (BPS). Production figures are given in total metric tons and do not distinguish by species. However, FAO's FIGIS dataset[3] breaks down cultured fisheries production by species (diadromas, pelagic, demersal, crustacean, mollusks, cephalopods, other marine fishes, and other freshwater fishes), which I use to estimate the value of production together with species-specific price data.

For commodity prices, the ideal measure would be the average price received by farmers, but the only data series with sufficient coverage available for Indonesia are wholesale prices. The FAO "producer price" series (available for most crop and livestock commodities since the mid-1960s) and Van der Eng's (1996) "rural

[2]I follow the Indonesian classification system for crop commodities whereby food crops (*palawija*) include rice, corn (maize), cassava, soybean, mungbean, and sweet potato; horticultural or garden crops include other vegetables and fruits; and estate crops include oil palm, rubber, coconut, sugar, coffee, cocoa, tea, tobacco, fiber crops, nuts, spices and other specialty crops.

[3]FIGIS and BPS's *Statistical Yearbook of Indonesia* define marine and freshwater fisheries differently but report nearly identical aggregate estimates of fish production for Indonesia (FIGIS includes harvest of aquatic animals, plants, and corals in aggregate fisheries production while the BPS yearbook excludes these species). In terms of resource use, BPS assigns all production from aquaculture (brackish or freshwater) to cultured fisheries while FIGIS allocates production to either marine fisheries (including brackish pond aquaculture) or inland fisheries (including cultured production and open water catches).

bazaar prices" for selected crops closely track the Jakarta wholesale commodity prices published by BPS (*Statistical Yearbook*). For this study I used *Statistical Yearbook* annual price series for 14 commodities (major food and estate crops, beef, and eggs) and FAO producer prices for horticultural crops and minor estate crops. Supplemental price data for some estate crops (cane sugar, kapok fiber, and ginger) are from the Indonesia Ministry of Agriculture (MOA). Van der Eng (1996) price data were used to fill in for gaps in the series, especially for the early 1960s. Fish prices for the eight categories of fish outputs are export prices derived from FAO trade data. For some commodities, consistent price series were established in Indonesia only in the late 1960s or early 1970s. For missing years, the average normalized price (commodity price relative to the price of rice) for the nearest five-year period for which price data were available were used to extend the series back to 1961. The normalized (relative) prices were then used to construct revenue shares for those years.

To account for marketing margins between prices received by farmers at harvest and at wholesale, I assume an average marketing margin for all commodities of 20%. Mears (1981), in a comprehensive study of rice marketing in Indonesia, estimated marketing costs between farm and wholesale levels in the late 1970s to be between 15% and 25% of the farmgate price of rice. While only one commodity, rice does account for about half of agricultural output in Indonesia. For the purposes of forming the agricultural output index, this assumption about the marketing margin is innocuous since it does not affect the relative prices among commodities, which are used to aggregate outputs. However, it does affect the cost share attributed to land, which is estimated as a residual after other costs are deducted from total revenue.

The land input measure includes five classes of agricultural land: irrigated cropland, other (rain-fed) terraced rice lands, area in garden and upland crops, area planted to perennial crops (including immature trees), and area in cultured fisheries. These data are from the *Statistical Yearbook of Indonesia* (supplemented with data from Van der Eng 1996 for some years), except for area planted to perennials, which is from MOA. The MOA data provide a more complete coverage of total area planted to perennial crops, including immature and other non-producing trees. The annual growth rate in total agricultural land is derived from a quality-adjusted aggregation of the different land classes. I assign quality weights to each type of land based on the average gross value of output per hectare of resource. Letting the quality weight for uplands be 1.00, the weights for the other land classes are as follows: 4.0 for irrigated wetland rice, 2.0 for non-irrigated wetland rice, 1.5 for cropland planted to perennials, 2.0 for freshwater ponds, 1.0 for brackish water ponds, and 0.5 for paddy fisheries. One way to interpret these weights is that they reflect (relative) returns to investments in land improvement. Agricultural land with more improvements in the form of irrigation, terracing, tree planting, and pond structures are more productive than land without these features and have a higher quality weight. The weight on paddy fisheries reflects the augmentation in resource value when fish are produced jointly with paddy rice.

For agricultural labor, I use FAO estimates of the number of economically active male and female adults in agriculture. Wages for male and female workers are average daily wages paid for crop weeding (BPS, *Farm Cost Structure of Paddy and Secondary Food Crops*). To find total annual labor costs, daily wages are multiplied by 300 days worked per year for men and 250 days worked per year for women. I adjust for improvements to labor quality by considering the average years of schooling of the agricultural labor force. To derive the effect of schooling on labor quality, I assume the increase in productivity from an additional year of schooling to be 7% for men and 8% for women, using Kawuryan's (1997, p. 218) estimate of the marginal private rate of return to primary schooling. Kano (2008) reports the share of the agricultural labor force with various schooling levels in 1971, 1980, 1990, and 2000, based on population censuses and SAKERNAS surveys. I estimated the average years of schooling for a worker in the agricultural labor force from these data by multiplying 0, 3, 6, 9, 12, and 15 years of schooling times the share of farm workers with no schooling, incomplete primary, completed primary, incomplete secondary, completed secondary, and post-secondary schooling, respectively, and interpolate for intervening census years.

Annual applications of chemical fertilizers (N, P_2O_5, and K_2O) are from FAO. Prices paid by farmers for fertilizers are from BPS *Agricultural Indicators*. Published data on pesticide inputs in agriculture are fragmentary. FAO reports tons of active ingredients of fungicides, herbicides, insecticides, and other chemicals consumed for 1990-1993 only. But these figures are substantially lower than those reported for 1980-1996 by Oudejans (1999), who obtained data from the agro-chemical industry. Based on Oudejans's figures and my estimate of aggregate agricultural revenue, it appears that pesticide costs did not exceed an 0.5% factor share in any year up through 1996. Because of the incompleteness of pesticides data, the data are not included in the input aggregation.

Mechanization in Indonesian agriculture remains relatively low compared with other Southeast Asian countries, and information on farm machinery capital inputs and their related costs is quite limited. In the 1970s there was widespread adoption of mechanical rice millers that replaced hand-pounding, which generated considerable controversy over rural labor displacement (Timmer 1998). In the 1990s the number of two-wheel walker tractors and water pumps grew rapidly from low initial levels. By 2001-05, only about 100,000 tractors (nearly all two-wheel) were in use among nearly 25 million farms, or about 1 tractor per 250 farm households. To measure agricultural machinery input, I estimate total tractor horsepower in use using the number of tractors by size (BPS, *Statistical Yearbook*) times the average horsepower per tractor for each size class. The annual cost of capital services is determined by estimating an annual service flow per horsepower and multiplying this by the total stock of horsepower of farm tractors. To estimate the annual service flow per horsepower, I use FAO data for the average import price for tractors and then amortize this price assuming a 10-year life span and a 10% discount rate. I then divide this cost by the average horsepower/tractor in service for each year to derive the annual depreciation cost of 1 horsepower of capital services. I then double this to account for other farm implement costs as well as fuel and repair costs.

Animal capital is measured as the annual stocks of buffalo, beef cattle, dairy cows, horses, pigs, small ruminants, and poultry (FAOSTAT). The relevant price weight for an animal input is the value of services from that animal in a given year. Prices for live animals are FAO import values for cattle, buffalo, horses, and sheep and export values for pigs and poultry. To derive annual service flows for long-lived species (large ruminants), the purchase prices are amortized over three years using a 10% discount rate.

Seed and feed inputs are from the FAO commodity balance sheets supplemented with feed data from the USDA's Production, Supply and Distribution database (PSD Online). The USDA data, which primarily cover raw materials used by commercial feed manufacturers, are used to measure feed from domestic and imported corn, by-products from wheat milling, and meal by-products from soybeans, oil palm, and copra and fish processing. FAO data are used for other sources of feed and include by-products from rice milling (bran and broken rice), molasses from sugar processing, tuber crops, meat meal, and milk fed to young animals. Feed prices are domestic commodity prices for rice, corn, and milk; FAO export values for rice bran, dried cassava, copra meal, oil palm meal, and molasses; and FAO import values for soymeal and fishmeal. Seed prices are set at 1.5 times the corresponding domestic commodity prices.

4.3. Results: Tornqvist-Thiel Indexes of Agricultural Output, Input, and TFP

Tornqvist-Thiel annual index series for aggregate agricultural output, input, and TFP are given in Table 12.8. The contribution of TFP to agricultural growth was relatively high during the 1960s and 1970s when green revolution crop varieties were widely adopted. During the 1980s, TFP growth slowed but resource expansion accelerated to sustain overall growth of the sector. The low growth during the 1990s partly reflects stagnation in productivity and the impact of the Asian financial crisis in 1997-98 when a sharp devaluation of the Indonesian currency caused the livestock sector, which was heavily dependent on imported feed, to sharply contract. In recent years (2001-2006), TFP growth rose to levels as high as or higher than the peak years of the green revolution. A number of factors may have contributed to the return to high TFP growth: adoption of improved technology, diversification into high-valued commodities, and land expansion into tree crops. The latter two factors affect TFP through resource-use efficiency rather than through technical change. By shifting the allocation of farm resources from production of lower-valued to higher-valued products, more real output is obtained per unit of input. Tree crop production can employ farm labor more fully over an entire year, especially when done in conjunction with food crop production on a farm, and thus increase hours worked per farm worker. Since labor is measured as the number of economically active workers, an increase in output due to a rise in average hours worked per capita appears in the estimation as an increase in TFP.

4.4. Policies and Productivity in Indonesia's Agricultural Development

In this section, I divide 1961-2006 into four periods, each reflecting a different policy orientation toward agriculture, and compare the growth performance of the sector during each period. The first period, 1961-1967, marks the final years of the Sukarno Guided Democracy era during which Indonesia suffered from macroeconomic and political instability. The second period, 1968-1992, reflects the early policies of Suharto's New Order regime when agriculture and food security were given precedence in economic policy. These policies included large state subsidies for agricultural inputs, intervention in markets for food staples, and the promotion of green revolution crop varieties. However, by the mid-

Table 12.8. Output, input, and total factor productivity (TFP) indexes for Indonesian agriculture

	Crops, Animals, and Aquaculture		
Year	Output	Input	TFP
1961	100	100	100
1962	106	102	105
1963	101	102	99
1964	106	102	104
1965	108	105	102
1966	112	105	106
1967	108	104	103
1968	126	112	112
1969	130	108	120
1970	139	109	128
1971	143	111	128
1972	144	113	128
1973	156	113	137
1974	161	115	140
1975	161	116	139
1976	161	117	138
1977	169	120	140
1978	178	124	144
1979	186	127	146
1980	203	129	157
1981	218	135	161
1982	217	139	157
1983	234	147	159
1984	253	154	165
1985	262	156	168
1986	281	162	173
1987	285	170	168
1988	299	173	173
1989	313	178	176
1990	326	184	177
1991	332	188	177
1992	359	193	186
1993	362	197	184
1994	364	204	179
1995	397	209	190
1996	401	213	188
1997	386	212	182
1998	383	205	186
1999	392	205	192
2000	404	207	196
2001	412	210	196
2002	435	216	202
2003	464	219	212
2004	486	219	222

Table 12.8. Continued

	Crops, Animals, and Aquaculture		
Year	Output	Input	TFP
2005	495	224	221
2006	510	225	226
Average annual growth rates (%)			
1961-1970	3.66	0.96	2.70
1971-1980	3.78	1.67	2.10
1981-1990	4.74	3.54	1.20
1991-2000	2.16	1.18	0.98
2001-2006	3.86	1.43	2.43
1961-2006	3.62	1.80	1.82

Source: Author's estimates.

1980s trade and fiscal imbalances led to a gradual shift in economic policies in favor of export-led manufacturing. Moreover, public subsidies and investments in agriculture began to wane (Fuglie and Piggott 2006). Diffusion of modern rice varieties and irrigated area as a share of total cropland both plateaued in the early 1990s (at about 80% of rice area and 14% of total cropland, respectively). Although there is no single date in which Indonesia's agriculture-first policy ended, I choose 1993 as the beginning date for what I call the "stagnation" period for Indonesian agriculture. Following the severe economic contraction and political crisis caused by the Asian financial crisis of 1997-1998, the country emerged with a new "reform" government and a more market-oriented agricultural policy. A sharp devaluation of the currency, liberalization of food crop markets, and changes in land-use policy shifted comparative advantage in agriculture toward export commodities like tropical perennials. The fourth period, 2002 to the present, I call a "liberalization" period in which market forces played a larger role in allocating resources to and within the agricultural sector.

The sources of agricultural growth during each of the four periods are shown in Table 12.9. For each period I decompose growth into the share explained by resource expansion and the share due to productivity improvement. I further decompose growth in labor productivity (output per worker) into changes in land per worker, capital per worker, education, and TFP.

During the first period of political and macroeconomic instability (1961-1967), agricultural output grew by only 1.24% per year, less than the rate of population growth. There were very few modern inputs employed in production and very little improvement in TFP. The estate crop sector was still depressed

Table 12.9. Sources of growth during episodes of Indonesia's agricultural development

Growth Measures	Stages: Instability 1961-1967	Stages: Green Revolution 1968-1992	Stages: Stagnation 1993-2001	Stages: Liberalization 2002-2006	Whole Period 1961-2006
	Average annual growth rate (%)				
Total output	1.24	4.82	1.51	4.31	3.62
Total inputs	0.71	2.47	0.93	1.36	1.80
Total factor productivity (TFP)	0.54	2.35	0.58	2.95	1.82
Workers[a]	0.02	0.29	0.01	-0.28	0.13
Output/worker[a]	1.23	4.53	1.51	4.59	3.49
Land/worker[a]	0.15	0.21	0.24	0.61	0.26
Other inputs/worker[a]	0.35	1.62	0.37	0.62	1.09
Education	0.19	0.35	0.31	0.41	0.33
TFP	0.54	2.35	0.58	2.95	1.82

Source: Author's estimates.

[a]The number of agricultural workers is measured in constant-quality units after adjusting for changes in the average schooling level of the agricultural labor force. Land includes land in crops and ponds, quality-weighted by type of land resource. "Other inputs" include all other measured inputs: animals, machinery, seed, feed, and fertilizer.

following the nationalization of foreign-owned estates in 1957 (Booth 1988), and efforts to boost productivity of food crops suffered from a lack of appropriate new technologies (Jatileksono 1987).

The growth performance of agriculture improved significantly during the green revolution period (1968-1992). The priority given by the New Order government to food crop production was greatly aided by the timely development of high-yielding rice varieties by the International Rice Research Institute in the Philippines. These varieties were well-adapted to irrigated agriculture in tropical Southeast Asia and responded well to higher levels of fertilizer (Darwanto 1993). Using revenues from oil exports, the government promoted the new varieties and heavily subsidized fertilizers and irrigation development (Jatileksono 1987). It also intervened in agricultural markets by restricting food imports and guaranteeing prices received by farmers (Timmer 2003). The New Order government also encouraged the expansion of cropland in sparsely populated regions of the country by subsidizing migration from Java and the planting of estate crops. A major program was the "nucleus estate" scheme in which plantation companies, in exchange for state-backed financing and long-term leases to public land, were obliged to provide processing and other services to smallholders in the areas surrounding the large estates (Potter and Lee 1998). During this green revolution stage (1968-1992), agricultural output growth accelerated to 4.8% per year. About half of this growth was due to resource expansion (including expansion of cropland, irrigated area, and fertilizer use) and about half to TFP growth. Growth in output per worker averaged 4.5% per year, which was driven by the increase in TFP as well as growth in material inputs (especially fertilizer) per worker. The growth in output per agricultural worker had a major impact on reducing rural poverty and food insecurity in the country (Timmer 2004).

By the early 1990s, modern crop varieties had been widely disseminated, but further sources of technological progress were not immediately forthcoming. The agricultural research system was apparently not sufficiently developed to deliver post–green revolution technologies that could sustain productivity growth (Fuglie and Piggott 2006). Further, the redirection of national priorities from agriculture to manufacturing reduced investments in the sector. Although food crops continued to receive trade protection and price supports, Indonesia became a large importer of cereal grains (wheat and feed grains, primarily). The livestock sector severely contracted during the Asian economic crisis when the currency was devalued and feed imports became prohibitively expensive (Simatupang et al. 1999). During the "stagnation" period (1993-2001), agricultural output growth averaged only 1.5% per year and TFP growth only 0.6% per year. Resource expansion slowed markedly, in part because of fewer resources for fertilizer subsidies and estate crop schemes, the end of government-sponsored migration, and the contraction in livestock capital during the 1997-98 Asian financial crisis.

By 1999 a new "reform" government was in power and the economy gradually recovered from the Asian financial crisis. One outcome of the crisis was liberalization of the agricultural sector: import restrictions on food crops were removed and fertilizer subsidies ended (Fuglie and Piggott 2006). Other policy changes, such as the 1999 Forestry Law and the 2001 Local Autonomy Law, affected control and access to public lands for agricultural development (Contreras-Hermosilla and Fay 2005). Between 2002 and 2006, agricultural growth resumed a rapid pace of over 4% per year and TFP growth accounted for about 60% of this growth. While the labor force remained almost constant, land per worker and other inputs per worker each grew by about 0.6% per year. The growth in cropland per worker occurred entirely outside of Java. Land expansion was particularly pronounced for tree crop plantings. By expanding area in estate crops, farmers could make fuller and more productive use of their labor during the agricultural season. Farmers who settled previously forested or degraded forest lands may have initially emphasized subsistence food crop production in "swidden" or shifting agricultural systems but gradually established mixed food-tree cropping systems involving oil palm, rubber cacao, coffee, and other perennials (Tomich et al. 2001; Belsky and Siebert 2003). The planting of tree crops was also a means of establishing tenure over these newly opened lands (Otsuka et al. 2001). On Java, meanwhile, agriculture also underwent intensification and diversification, with resources shifting from food and estate crops toward higher-valued horticulture, animal, and aquaculture production. However, the expansion of crops onto previously forested areas has raised environmental concerns. Soil erosion from cropland (Lindert 2000), biodiversity losses from forest conversion to oil palm monoculture (Koh and Wilcove 2008), and greenhouse gases emitted from peatland drainage (Couwenberg, Dommain, and Joosten 2009) have been found to be substantial, although these changes appear to primarily affect the supply of ecological services and not agricultural productivity.

Finally, Table 12.9 shows a steady but growing contribution of farmer education to productivity growth. Over the 1961-2006 period, the increase in average farmer education accounted for about 10% of the total growth in agricultural labor productivity. Moreover, the contribution of education to growth gradually increased over time. Since the early 1990s, the agricultural labor force has increased primarily in quality rather than quantity. It is likely that before the end of this decade agricultural employment in Indonesia will be in absolute decline. Raising the educational level of agricultural workers can offset this decline so that the transfer of labor from agriculture to other sectors will not be a drag on agricultural growth.

5. SUMMARY AND CONCLUSION

In the early years of the twenty-first century, agriculture in Indonesia reemerged as a dynamic sector of growth following a decade of post–green revolution stagnation. Once heavily dominated by rice production, the country's agriculture has become increasingly diversified, with perennials, horticultural crops, livestock, and aquaculture growing in relative importance over time. Indonesia has become a significant global supplier of tropical vegetable oil, rubber, cocoa, coffee, fish, and shrimp. Although the country continues to rely on imports for a significant share of its cereal grain needs for food and feed, it maintains a positive agricultural trade balance overall.

Resource expansion and productivity improvement have been important sources of growth in Indonesian agriculture. Agricultural land continues to expand in the sparsely populated regions of the country where area planted to perennial crops, oil palm especially, has undergone rapid expansion in recent decades. These regions include the islands of Sumatra, Kalimantan, Sulawesi, and Papua. Both smallholder farms and large estate companies are heavily involved in the perennial-crop sector. Large estate companies, with better access to capital and technology, often dominate the early stages of perennial crop development, but over time, smallholders catch up. Presently, smallholders dominate the production of rubber, coffee, cocoa, and coconut and are gaining market share in oil palm. Yield gaps between smallholders and large estates have also diminished over time. Nonetheless, cropland expansion into previously forested areas and peatlands has raised serious concerns about the loss of ecological services such as greenhouse gas sequestration and biodiversity preservation. The trade-off between agricultural and environmental outputs from these resources is an important issue needing further exploration.

Growth accounting provides a useful tool for assessing and decomposing sources of economic growth. Using the Tornqvist-Thiel index method, I find that Indonesia achieved an annual growth rate in agricultural production of 3.6% over the 1961-2006 period. Slightly more than half of this growth can be attributed to improvement in total factor productivity and the rest to resource expansion (increases in land, labor, capital, and intermediate inputs). Over the course of 1961-2006, agricultural labor productivity (in quality-adjusted units) increased at an average annual rate of 3.5%, and higher levels of schooling in the farm population accounted for about 10% of this growth. Continued improvement in the quality of labor can offset the expected decline in the size of the farm labor force in coming years.

Total factor productivity growth in agriculture accelerated during the green revolution period (1968-1992) when the government followed an agriculture-first development strategy and modern varieties of food crops were widely disseminated. However, TFP growth stagnated in the 1990s and did not resume until the country recovered from the Asian financial crisis and liberalized its policies toward agriculture. It appears that commodity diversification has been an important source of measured TFP growth in recent years. Farmers increased productivity by moving to more intensive production systems involving perennials, horticulture, animals, and aquaculture as well as food crops. This not only shifted resources to the production of higher-valued commodities but also made fuller use of farm labor. Moreover, the private sector rather than the state appears to be the driving force behind the reemergence of growth in this sector. Nonetheless, the gains from diversification were preceded by an impressive improvement in productivity of rice and other food staples. Having first secured food security may well have encouraged smallholder farmers to allocate more resources to producing non-staple commodities for the market.

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