Chapter 4

POLICY OPTIONS FOR INDUCING A SUPPLY RESPONSE

Hiroyuki Takeshima

As the previous chapter notes, paddy yields in Nigeria are among the lowest in the region and well below other developing countries in Asia and Latin America. Additionally, the chapter highlights Nigeria's untapped biophysical potential for expanding rice production and output with improved water access in lowlands and other areas suitable for irrigation. The current low yields alone imply that the country has the potential to transform the sector by simply closing existing yield gaps. More specifically, a number of technological and socioeconomic constraints, together with past public investments and price policies, have inhibited the wider diffusion and use of improved technologies and farming practices, implying an untapped potential to induce a supply response and transformation of the sector.

The objective of this chapter is to examine empirically some of the key economic factors affecting the profitability of paddy rice production at the farm level and, given these current conditions, estimate whether price incentives are able to induce an aggregate supply response at the national level. The types of public-sector interventions needed to promote output growth are also explored, drawing on lessons and experiences from other major rice-producing regions in the developing world. The chapter specifically focuses on irrigated and lowland production systems because, as shown in Chapter 3, these systems have the greatest potential for rice-production growth in Nigeria. Understanding the microeconomics of these systems can provide important insights into the constraints affecting rice-production growth, despite recent government efforts to introduce price incentives through higher import tariffs.

The chapter begins by analyzing a number of representative farm budgets from selected locations in Nigeria in order to compare and contrast their profitability across different input-intensive production systems. The findings show that the constraints on profitability are related not so much to intensification but to the current set of technologies in use, which are evidently undermining the potential yield gains from such intensifications.

Next, I examine the degree to which these constraints affect the government's ability to generate a significant supply response in the sector through price incentives. This is accomplished by empirically estimating an aggregate supply response and area response of irrigated rice production using nationally representative data. Results show that the aggregate supply response to price incentives in Nigeria is low. I hypothesize that this is partially due to insufficient past investments in agricultural research and development (R&D) and irrigation infrastructure as compared with the lessons and experiences from elsewhere in the region and other major rice-producing countries in Asia and Latin America. The final section summarizes the key findings of the review and analysis before concluding the chapter.

The data used in the empirical analysis of this chapter are based on information from the Nigerian Living Standards Measurement Study–Integrated Surveys on Agriculture (LSMS–ISA) (Nigeria, NBS and World Bank 2011, 2013) data discussed in Chapters 2 and 3 and the author's own fieldwork in 2013. The supply response analysis uses the agricultural module of the LSMS data, as they contain information on the quantity of rice harvested and use of various inputs and technologies on plots where rice is grown. The fieldwork was necessary to fill in gaps, as information in the literature on the microeconomics of these production systems in Nigeria is relatively scarce.

The data from field visits were collected in the following manner. First, given distinct production environments between the two geopolitical zones that produce the bulk of paddy rice in Nigeria, North West and North Central, locations were sought in both zones. The geopolitical zones are illustrated in Figure 1.1 in Chapter 1. To select the locations, the local government areas (LGAs) where one of two possible rice irrigation methods (river diversion or lifting of groundwater) is observed were identified from the LSMS–ISA (2011, 2013). I then asked the extension agents in those LGAs to take me to the rice irrigators they know. This is because farmers are more likely to provide detailed information about their rice-production practices to the agents with whom they are familiar.

Although I am likely to have visited producers who are relatively wealthier and better connected with the extension agents, they are also more likely to have better knowledge on the most efficient production practices, and therefore they represent an upper bound of the profitability of their systems. This becomes especially important if such an upper bound is low, implying that for most other farmers, production is less likely to be profitable. In addition, I focused on visiting a small number of rice producers in order to measure the plot size accurately, instead of surveying a larger number of producers. This is important because in African countries where plots are not regularly demarcated, farmers' measurements of plot sizes are often incorrect (Carletto, Savastano, and Zezza 2013), leading to biased estimates of yields or production costs that are measured per hectare of area.

In addition, it is necessary to ask about and validate the costs of different inputs and activities in a highly disaggregated manner, because aggregating across different cost items often leads to the underestimation of total cost figures (Deaton 1997). To address these issues, 14 samples were collected across different rice-production ecologies and geographic areas, which are small in terms of sample size but more accurately measured. However, even these conclusions would need to be interpreted with caution given the small size and nonrandom nature of the sampling procedure. Moreover, results may vary from year to year due to factors such as weather conditions or even individual specific shocks that would affect profitability in a particular location at the time of the field visit. Future studies will need to examine whether the key messages of this section, particularly those derived from fieldwork, are sufficiently representative and apply to rice production in other production environments.

Assessing the Profitability of Paddy Rice Production

As the previous chapter showed, many socioeconomic constraints affect rice production in Nigeria, including the degree of access to markets, credit, and extension. But even more important is the viability of new technologies in ensuring a positive return to the farmer, given input and output prices, resource requirements, and costs (e.g., labor, land, and capital). All these affect the profitability of rice farming. This section delves deeper into assessing the profitability of paddy rice production based on farm budgets. More specifically, it uses data from the author's field visits, as described above, to analyze some of the key characteristics of rice-production costs and their implications for profitability at the farm level within each of the selected rice ecologies.

Generally, the intensity of modern input use for rice production varies widely across different rice ecologies and regions within Nigeria. Table 4.1 summarizes performance, input use, and production costs in irrigated and

TABLE 4.1 Rice-production performance, input use, and costs in selected locations in Nigeria based on farmer interviews, 2013

Location of interviewed farmers										(11) System			
(1) State	(2) Local government area	(3) Plot size (ha)	(4) Yield (tons/ha)	(5) Nitrogen (kg/ha)	(6) Fertilizer (kg/ha)	(7) Variety	(8) Gross revenue (US$/ha)	(9) Production cost (US$/ha)	(10) Labor cost (US$/ha)	IRR (pub)	IRR (pri)	RF (d)	RF (s)
North West zone													
Zamfara	Talata-Mafara	0.28	5.5	136	536		2,480	2,237	1,134	•			
Zamfara	Talata-Mafara	0.24	6.8	158	625		2,823	2,171	859	•			
Kebbi	Argungu	1.40	5.4	300	1,071	FARO 44	2,765	2,469	1,135		•		
Kebbi	Bunza	0.25	6.1	187	406	FARO 44	3,141	2,376	1,474			•	
Kano	Karaye	0.89	4.6	185	673	TOX	NA	NA	NA				•
Kano	Karaye	0.23	3.8	160	641	yardus	NA	NA	NA				•
Jigawa	Kilikasamma	1.37	6.5	240	728	WITA 4	NA	NA	NA		•		
Jigawa	Kilikasamma	2.02	3.3	119	395	WITA 4	NA	NA	NA		•		
North Central zone													
Nasarawa	Lafia	1.51	2.7	105	331	FARO 15	1,500	1,417	501			•	
Nasarawa	Lafia	0.70	2.3	30	143	FARO 44	1,790	1,802	1,241		• (rd)		
Nasarawa	Lafia	0.75	1.6	60	268	FARO 44	NA	NA	NA		• (rd)		
Nasarawa	Lafia	1.35	1.4	34	56	FARO 44	777	393	148			•	
Nasarawa	Karu	1.00	3.0	83	350	NERICA	2,065	2,116	985		•		
Nasarawa	Awe	1.35	2.8	0	0	FARO 44	1,553	1,359	666				•

Source: Author's fieldwork, May–July 2013.

Note: IRR = irrigated; RF = rainfed; pub = publicly operated; pri = privately operated; d = deepwater; s = plots submerged much of the season from rainfall; rd = river diversion; NA = not available. NERICA = New Rice for Africa.

rainfed lowland ecologies.[1] These are ecologies that have greater potential for rice-production transformation relative to upland ecologies, which tend to be more subsistence oriented and therefore targeted more for food security and poverty reduction objectives.

An interesting outcome from analyzing the available data is the finding that in many locations, except where public irrigation and some deepwater systems exist in northern Nigeria, net profits are small relative to production costs, where net profit is calculated by subtracting production cost in column 9 from gross revenue in column 8. This pattern has important implications. First, there are rice farmers who do not seem constrained from using modern inputs. This is contrary to the general view that African farmers are typically underutilizing modern inputs due to credit constraints or other market imperfections (Awotide et al. 2013; Kelly, Adesina, and Gordon 2003; Morris et al. 2007; World Bank 2007), in which case production costs per unit of land would be much lower. In fact, fertilizer use per hectare among interviewed farmers was found to be considerably high, particularly in the North West zone.

Second, these rice farmers may actually be overusing some of the inputs, with the exception of land. This is because of the following logic: as the underlying production system begins to exhibit diminishing returns to scale given generally older technologies being used on the same plots of land, marginal costs of modern inputs rise, but because rice prices are high, farmers continue using these inputs. This is reflected in Table 4.1 by higher yields in the North West zone being observed on smaller rice plots. Consequently, the smaller net revenues are likely the results of farmers operating beyond the optimal level of input use that would maximize net revenue. This is also partially supported by the evidence presented in the next section, which demonstrates that variable input costs such as labor and irrigation pumping seem to account for a greater share of total production costs than fixed costs. An important implication of this finding is that if farmers are already overusing modern inputs, efforts to stimulate supply response through the promotion of these inputs may be limited. In other words, the price elasticity of supply would be low.

1 Table D.2 in Appendix D summarizes rice production costs in upland, lowland, and irrigated ecologies across Nigeria reported in other selected studies. Many studies, however, do not clarify how plot sizes were measured. The International Food Policy Research Institute's fieldwork found that farmers often over-report the size of plots, leading to inaccurate figures of yield and costs. This discussion is therefore focused on the figures in Table 4.1, which were all calculated using Global Positioning System–measured plot sizes.

Partial Budget for Irrigated Rice Ecologies

Table 4.2 presents the selected farm budgets for irrigated rice ecologies. Zamfara and Kebbi States are located in the northwestern part of the country (North West zone), while Nasarawa State is located in the central part of the country (North Central zone) (see Figure 1.1 in Chapter 1 for the locations of states and definitions of the six geopolitical zones). Intensive irrigation systems comparable to Asia can be found in parts of northern Nigeria, and these production systems are rather costly (columns 3 and 4).

Typically, production practices consist of land preparation that is done either mechanically or manually, transplanting or broadcasting of seeds ("planting" in Table 4.2), applications of fertilizer and agrochemicals, and production management such as weeding and bird scaring. Harvesting is done mostly manually, while threshing is sometimes done mechanically. In certain

TABLE 4.2 Rice farm budgets in irrigated ecologies

(1) Categories Irrigation systems Varieties	(2) Unit	(3) Zamfara Public scheme FARO 44		(4) Kebbi Private-pump FARO 44		(5) Nasarawa River diversion FARO 44		(6) Nasarawa Private-pump New Rice for Africa	
Plot size (ha)		0.28		1.40		0.70		1.00	
Values		Qty	US$/ha	Qty	US$/ha	Qty	US$/ha	Qty	US$/ha
Nonlabor cost									
Land preparation									
Harrowing	Number	2	230					1	48
Plowing	Number							1	65
Fertilizer									
NPK	50 kg bag	2	253	17	431	1	51	5	161
Urea	50 kg bag	1	120	13	300	1	55	2	77
Transportation	50 kg bag	3	14						
Seeds	Kg	75	138	75	28	68	55	60	29
Chemicals									
Pesticide	Liter			1	18				
Herbicide for land preparation	Liter					5	41	10	52
Herbicide	Liter	1	35	4	16	NA	77	NA	43
Threshing (nonlabor part)	75 kg bag	20.5	47						
Empty bag	Number					18	17	40	18
Paddy transportation to the market	75 kg bag	20.5	24			18	33	1	32

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Plot size (ha)		0.28		1.40		0.70		1.00	
Values		**Qty**	**US$/ha**	**Qty**	**US$/ha**	**Qty**	**US$/ha**	**Qty**	**US$/ha**
Labor cost									
Land preparation	Number			1	55	1	230	1	32
Plowing	Number					1	138		
Leveling	Number					1	66		
Diking/bunding	Number	1	69			1	37		
Nursery preparation	Number			1	10				
Planting	Number	1	230	1	166	1	14	1	97
Weeding	Number	2	92	1	166	1	226		
Fertilizer application	Number	3	35	1	28	1	18	1	26
Herbicide spraying	Liter	1	5	4	9	1	51	1	19
Irrigation application	Number							1	398
Bird scaring + pest control	Number	1	461	1	415	1	194	1	45
Harvesting	Number	1	115	1	111	1	166	1	129
Threshing/bagging	Number	1	115	1	176	1	332	1	129
Loading/off-loading	75 kg bag	20.5	12						
Irrigation cost	Season	1	12						
Pump	Number[b]			0.25	58			0.67	95
Hose	Number[b]							0.2	28
Fuel	Liter			1,050[c]	484			582	547
Channel construction	Number							1	45
Renting of land	Season	1	230						
Total cost (US$/ha)			**2,237**		**2,469**		**1,802**		**2,116**
Total labor cost (US$/ha)			1,134		1,135		1,241		985
Gross revenue (US$/ha)	75 kg bag	20.5	2,480	100	2,765	21	1,790[d]	40	2,065
Net revenue (US$/ha)			243		296		–12		–51
Yield (ton/ha)			5.5		5.4		2.3		3.0
Paddy prices (US$/kg)			0.46		0.51		0.78		0.69
Nitrogen (kg/ha)[a]			136		300		30		83

Source: Author's fieldwork, May 2013.

Note: The information is based on a single farmer for each location. However, I also validated each piece of information on individual activities with other farmers in each location. Blank space indicates that the interviewed farmer did not use the inputs; therefore, the related activities and payments do not apply. NPK and urea are fertilizer products, while nitrogen is one of the chemical components of these fertilizer products. [a]Calculated assuming NPK 15-15-15 (15% nitrogen component) and urea 46%. [b]The interviewee buys an irrigation pump once every few production seasons. For example, if they buy a pump every four production seasons, figures are converted into 0.25 = 1/4. Similar calculations are applied to hoses. [c]35 liters/day, one application every 3 days for 3 months (or 30 days in total). [d]Price reported by this farmer was unusually high. I therefore used the average of the figure reported by the farmer and averages among other farmers I interacted with in the same area.

cases, payment for empty bags is made separately from threshing and bagging; in other cases, payment is made all at once. Similarly, payment for loading and off-loading of 75 kg bags of paddy is sometimes made separately from paddy transportation to the market, while in other cases it is included in the transport payment.

Irrigated rice production is labor intensive, with labor costs generally more than US$1,000/per hectare (ha), accounting for about half (or more) of total production costs. Irrigation costs are also high if the system is pump based. Fuel costs for running pumps alone are about US$500/ha per season. These costs can be affected by various factors, including irrigation efficiency and pump capacity. In the North Central zone, paddy prices are slightly higher than the North West. Despite such intensive use of labor and irrigation, however, yields are quite modest and net revenue is, at best, barely positive (after adjusting for the opportunity costs of family labor).

Columns 3 and 4 of Table 4.2 also present the exceptionally high yielding cases observed in parts of northern Nigeria: an irrigation scheme in Zamfara State and a pump-based private rice irrigation system in the *fadama* area (a Nigerian term for an inland valley bottom) of Kebbi State. Their observed yields of 5.4 to 5.5 ton/ha are quite comparable to some of the successful rice irrigation systems in Asia. As was discussed earlier, these regions share similar ecologies with the Office Du Niger in Mali or in the Senegal River Valley, where Asian varieties are found to be most attractive given their geographic latitude. These production systems are, however, costly (with per hectare production costs at around US$2,200 to US$2,500) and likely to be feasible only in highly limited geographical areas with sufficient access to water, soils, and varieties. This type of ecology accounts for only a small fraction of the northern rice-growing regions.

Partial Budgets and Fertilizer Use for Rainfed Lowland and Upland Rice Ecologies

Production practices in some rainfed lowland areas are also characterized by high production costs, with total costs exceeding US$1,000/ha (columns 3 and 4 in Table 4.3). Production is somewhat labor intensive, with labor costs exceeding US$500/ha. In the lowland rice ecology, water control has also been suggested by the farmers to be a critical constraint to intensification and maximizing yield potential. Land preparation methods in these lowland systems become very critical in this regard, including the use of herbicides and tractors. Total costs of herbicides can be around US$200/ha. In some cases, soil is fertile enough so that no fertilizer is used.

TABLE 4.3 Crop budgets for rainfed rice (selected locations in Nasarawa State based on ecological status)

		Ecologies					
(1) Categories	(2) Unit	(3) Deepwater		(4) Lowland		(5) Upland	
Varieties		FARO 15		FARO 44		FARO 44	
Plot size (ha)		1.51		1.35		1.35	
Values		**Qty**	**US$/ha**	**Qty**	**US$/ha**	**Qty**	**US$/ha**
Nonlabor cost							
Harrowing (tractor)	Number	1	94	1	119	1	72
Fertilizer							
NPK	50 kg bag	8	188				
Urea	50 kg bag	2	51			1.5	39
Seeds	100 kg bag	1	96	2.25	143	0.5	32
Chemicals							
Chemicals for land preparation[a]	Liter	22	150			NA	30
Herbicide	Liter	22	220	36	178	2	19
Empty bag	75 kg bag	54	23	50	24	25	14
Rope for bird scaring	Number			70	3		
Transport harvest to the market	75 kg bag	54	46	50	153	25	24
Labor cost							
Land preparation	Number	1	47	1	72	1	14
Plowing	Number					1	72
Broadcasting	Number	1	17	1	24	1	5
Fertilizer application	Number	1	17			1	10
Weeding	Number	1	81			1	19
Herbicide spraying	Liter	36	108	36	69	2	5
Bird scaring	Number			1	287		
Harvesting	Number	1	98	1	143	1	38
Threshing	Number	1	180	1	143		
Total cost (US$/ha)			**1,417**		**1,359**		**393**
Total labor cost (US$/ha)			501		666		148
Gross revenue (US$/ha)	75 kg bag	54	1,500	50	1,553	25	777
Net revenue (US$/ha)			83		194		384
Yield (ton/ha)			2.7		2.8		1.4
Paddy prices (US$/kg)			0.56		0.55		0.56
Nitrogen (kg/ha)			105		0		34

Source: Author's fieldwork in July 2013. Exchange rate = 155.

Note: Blank space indicates that the interviewed farmer did not use the inputs; therefore, the related activities and payments do not apply. [a] The quantity of chemicals for land preparation in column 5 was not available, although the respondent remembered their cost.

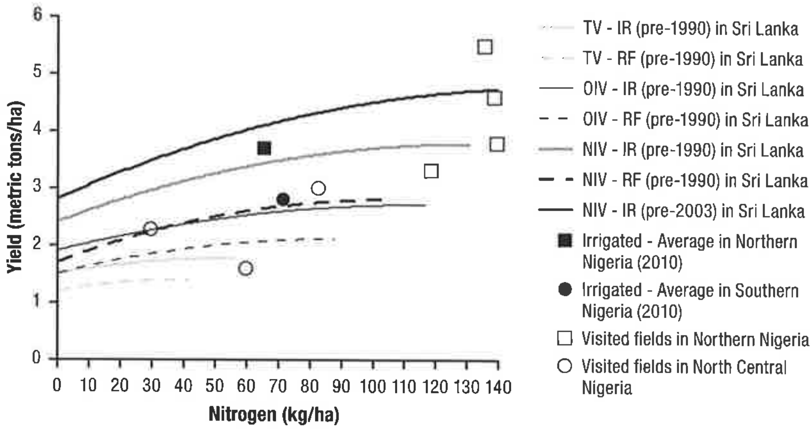
Production practices in upland rice ecology (column 5) are still generally primitive. Despite low yields because production is less input intensive, the system still brings in more profit than in the rainfed lowland or irrigated ecologies (US$777 in revenue minus US$393 in cost = US$384/ha, compared to lower figures in other ecologies). Tables 4.2 and 4.3 suggest that production costs in irrigated rice environments can be much higher than in upland environments, particularly due to irrigation and labor costs.

One option may be to fully exploit the limited but undeveloped irrigable areas in northern Nigeria through rehabilitation of many public irrigation schemes, such as removing sediments from the dams and canals or plot leveling, which can reduce the water delivery costs to and within the plots. Many of the existing dams were also constructed without a full assessment of their environmental impact. This has led to negative externalities created by many of these schemes, such as Bakolori Dam, located in Zamfara State (Yahaya 2002), and Tiga Dam, located in Kano State (Thomas and Adams 1999). If the rehabilitation of existing schemes is successful, this can affect the production in surrounding areas. Expansion of irrigation is needed for rice intensification and increased supply response, but it needs to be carefully designed through detailed hydrological, topographical, and socioeconomic analyses, so that the negative environmental externalities are minimized.

These partial budget analyses provide some useful insights into the supply response potential of rice in Nigeria. First, labor costs account for a significant share of rice-production costs, meaning that rice production (particularly in irrigated and rainfed lowland environments) is labor intensive. It is often difficult to expand the cultivated area of labor-intensive production because costs of supervising and monitoring hired workers increase significantly. Second, current net revenue in irrigated and rainfed lowland rice production is generally low. Some farmers earning greater income from the production of other crops or upland rice may not have much incentive to switch to rice production, unless net revenues increase significantly. However, since the costs of nonlabor inputs (particularly seeds) are generally small, subsidizing them may not substantially increase the net revenues.

Aside from the analysis of partial budgets, an examination of the degree of fertilizer use and its effectiveness in raising rice yields is also useful considering that it is one of the essential inputs for rice intensification. However, evidence of its ability to effectively induce an overall supply response through favorable fertilizer prices has been limited. Figures indicate that the rice fertilizer response in Nigeria is still low, particularly in the North Central zone and the southern (South East, South South, and South West) zones.

FIGURE 4.1 Nitrogen response for rice in Nigeria: Comparison with estimates based on Sri Lankan data



Source: Yield response lines are from Kikuchi and Aluwihare (1990) for all pre-1990 figures; Kikuchi, Maruyama, and Hayami (2003) for the pre-2003 figure. The irrigated averages are based on LSMS data from Nigeria, NBS and World Bank (2011), while data from author's own fieldwork are included to provide additional data points.

Note: IR = irrigated, RF = rainfed, TV = traditional variety, OIV = older improvement variety, NIV = newer improved variety.

For comparison, Figure 4.1 plots the nitrogen response curves of various generations of improved varieties (rainfed and irrigated) in Sri Lanka, which illustrate nicely the generational varietal improvement process starting from traditional varieties (TV), older improved varieties (OIV), newer improved varieties (NIV) introduced before 1990 (pre-1990), and newer improved varieties introduced before 2003 (pre-2003).[2] The observed yield and nitrogen levels under irrigated (IR) conditions in Nigeria are plotted against these curves. Importantly, the fertilizer response levels in the North Central zone and three southern zones in Nigeria are similar to OIV–IR (pre-1990).

Some of the dots from the North Central Nigerian zone (o) in Figure 4.1 indicate the variety FARO 44, which is relatively successful in the north. In other words, improved varieties (including FARO 44) currently used in the North Central and southern zones may be only as good as improved varieties that were already considered relatively old in Sri Lanka by 1990 for this ecology. Even in northern Nigeria, fertilizer response is close to the NIV–IR (pre-1990) and below NIV–IR (pre-2003), indicating that the improved varieties

2 While I do not have the exact sequencing of the development of these different groups of varieties, varieties developed later are likely to have better fertilizer responses.

currently used in the north are only as good as varieties that were considered new in the 1990s and are likely to be more obsolete by now. Only a handful of locations in the north achieve the similar level as NIV–IR (pre-2003). These conditions in Nigeria are consistent with the hypothesis that rice variety development in Nigeria has been trailing behind that in countries such as Sri Lanka. Given the long tradition of rice production, crop husbandry knowledge might not be the major reason for this gap.

Estimating an Aggregate Supply Response

Having looked at the farm-level profitability of rice-production systems, it is appropriate to examine the sector's overall responsiveness to price incentives. This is done by estimating the price elasticity of farmgate rice supply and the irrigated rice area, aggregated across rice producers in Nigeria. A price elasticity of rice production measures the degree to which a unit proportional change in output prices results in a proportional change in production output or area cultivated, which is an important indicator of supply responsiveness. The data used are from the LSMS–ISA (2011, 2013) discussed in earlier chapters, as well as other data indicating the spatial and temporal variations of agroecological and socioeconomic conditions. The LSMS–ISA data are appropriate because the two rounds of the survey (from 2011 and 2013) allow construction of a pseudo-panel dataset. Constructing such a dataset makes it possible to control for various district-specific unobserved factors (such as the history of rice production in the area and average farmers' production skills) that affect rice-production practices separately from observable factors.

Appendix D provides the detailed empirical specifications, econometric methods used, regression results, and procedures for calculating elasticities. This section provides a brief summary of these aspects. The underlying model is based on agricultural household models by Singh, Squire, and Strauss (1986), where a household facing credit constraints and transaction costs determines rice-production levels in a process of maximizing household utility, given the prices of rice and other competing crops, as well as prices of key inputs and access to technologies such as irrigation and mechanization.

Using a reduced-form supply-response estimation technique, the degree to which rice-production decisions have responded to recent rice-price changes in Nigeria is assessed. Farmers' decisions typically involve two steps: a decision to grow rice followed by a decision on how much to grow. Because of high transaction costs involved with market participation in rural Africa, the first decision may be made in a different mechanism from the second decision. Many

TABLE 4.4 Price elasticity of rice production and irrigated rice area in Nigeria

(1) Variables	(2) Own-price elasticity	(3) Standard error of estimated elasticity
Rice production	0.23	0.12
Irrigated rice area	0.08	0.19

Source: Author's estimation based on Nigeria, NBS and World Bank (2011, 2013).

studies have addressed these types of price-incentive responses in Africa (see, for example, Heltberg and Tarp 2002; Takeshima and Winter-Nelson 2012). Their models are extended by applying Cragg's (1971) double-hurdle model to estimate rice-production response and the Tobit model to estimate irrigated rice area response. The Tobit model is used for the irrigated rice area due to the small sample size of rice irrigators, for which the double-hurdle model is inapplicable.

The panel nature of the LSMS datasets is explored to apply a modified correlated random effects model, which can partly control for location-specific unobserved characteristics in specifications with limited dependent variables such as the double-hurdle or Tobit models (Takeshima and Nkonya 2014).[3] Because the model specification is a reduced form, it does not distinguish the effects of endogenous factors. For example, it does not model the intermediate steps such as renting additional land, transaction costs for hiring labor for land clearing, and so on that are required to start and expand rice production. Similarly, the analysis remains at the household level; although a higher price in the market would actually lower demand, I am not modeling market-level supply and demand functions.

Estimated price elasticities of rice production and irrigated rice areas are presented in Table 4.4 (detailed regression results are in Table D.1). Results in column 1 in Table D.1 indicate that a 100 percent increase in rice price may raise the probability that the farmer grows rice by 7 percent, which is calculated by summing the coefficients on "local rice/yam" (0.022), "local rice/cassava" (0.042), and "local rice/maize" (0.006) (ignoring the statistical significance for now, which is discussed below). Using the formula for the partial effects (*PEs*) in Appendix D, the same 100 percent increase in rice price is calculated to increase rice output by 0.622 tons (a number reached by summing the "local rice/yam," "local rice/cassava," and "local rice/maize" coefficients in column 3 in Table D.1) and the irrigated rice area by 0.018 ha (column 7 in Table D.1).

3 Technical details of the model and analysis are provided in Appendix D.

All three of these effects—the 7 percent probability increase, 0.622 metric tons increase in output, and 0.018 ha increase in irrigated rice area—are statistically significant. The price increase, however, has no effect on the decision to grow irrigated rice. Using the formulas shown in Appendix D, the estimated price elasticity of rice production is around 0.23. The estimated price elasticity of the irrigated rice area is 0.08, which statistically is not significantly different from zero. The estimate for the supply elasticity is close to those of others such as Rahji, Ilemobayo, and Fakayode (2008), who find a long-run estimate of around 0.24 and 0.33. Their short-run estimates were 0.06 to 0.08. Overall, the results are consistent with the view that rice production is only marginally responsive to rice prices in Nigeria. In particular, rice prices have fairly small effects on the expansion of the irrigated rice area, which is critical for yield growths.

The estimated supply elasticity is not any higher than other more advanced rice economies, and it seems to have declined recently. Price elasticities of rice supply in many Asian countries with larger rice-production sectors and more mature production technologies than Nigeria have been around 0.2 in the short run, with the exception of Bangladesh (Table 4.5, column 2). In Vietnam, the price elasticity of the irrigated rice area was around 0.17 in the early 1990s, when the share of irrigated area was already close to 50 percent (column 3).

In Nigeria, the supply elasticity of upland rice was estimated in the 1970s to be around 0.5 to 0.6 (Ngambeki and Idachaba 1985), while the average at the national level, as noted earlier, has been estimated between 0.24 and 0.33

TABLE 4.5 Price elasticity of rice supply in Nigeria and other countries

(1) Country	(2) Price elasticity of rice production	(3) Price elasticity of irrigated rice area
Nigeria	0.5–0.6 (Ngambeki and Idachaba 1985; upland rice in the 1970s)	
	0.24–0.33 (Rahji, Ilemobayo, and Fakayode 2008)	
Bangladesh	1.1 (Imai, Gaiha, and Thapa 2011)	
Thailand	0.25 (Choeun, Godo, and Hayami 2006; short run)	
	0.59 (Choeun, Godo, and Hayami 2006; long run)	
	0.2–0.3 (Behrman 1968; in the 1960s)	
Vietnam	0.22 (Khiem and Pingali 1995)	0.17 (Khiem and Pingali 1995)
Elasticity figures assumed		
West Africa	1.0 (Dalton and Guei 2003)	
Japan	0.2 (Hayami and Ruttan 1970)	
Senegal	0.3 (Fisher, Masters, and Sidibé 2001)	

Source: Author's compilations.

(Rahji, Ilemobayo, and Fakayode 2008). Current price elasticities of rice supply in Nigeria seem low considering that the rice sector is still relatively small compared to that in Asia and the yield gap is greater.

The low price elasticity of rice production and irrigated rice area in Nigeria is consistent with the hypothesis that technologies are still underdeveloped for rice production, so that price policies alone have limited effects on rice production. Moreover, a higher rice price appears to provide little incentive for farmers to expand the irrigated rice area, not only because soils suitable for irrigated rice are relatively limited in Nigeria but also because varieties are old, with quickly diminishing returns to water, and public irrigation schemes have been relatively underinvested given the size of arable land, so that costs of delivering irrigation water to the plots remain high.

Policy Implications and Role of the Public Sector

Rice production and technology adoption decisions by farmers are affected by economic returns, and these returns must be substantially high in order to overcome various market failures and weak infrastructure that constrain rice production in rural Nigeria and thus an aggregate supply response. Historically, key public interventions that raised economic returns in Asia and Latin America were investments in improved varieties, expanded irrigation, and incentives through price policies. On the other hand, the development and use of mechanization technologies and other modern inputs such as fertilizer seem to have grown endogenously (Pingali 2007), partially in response to the seed and irrigation technologies initially invested in by the public sector, but also in response to rising real wages, among other factors. In fact, public expenditures on agrochemicals during the Green Revolution era were generally small, only a fraction of fertilizer expenditure, while much of the focus was on developing pest-resistant rice varieties (Barker, Herdt, and Rose 1985, 90) and irrigation.

The design and development of machinery suitable for certain uses and local environments in rice production systems were often led by the private sector and through adaptive innovations from direct interactions with farmers. This was important, as both agroclimatic factors (soil, terrain, rainfall) and economic factors (land, labor, capital, farm size, materials available) can greatly affect the efficiency and suitability of different mechanized technologies in different locations (Binswanger 1986). Examples of such adaptive innovations in the past include those in the United States (Evenson 1982), India's Punjab region (where a diversified machinery industry emerged from

TABLE 4.6 Drivers of rice-production growth in selected Asian countries, 1965–1980

(1) Country	Output increases, thousand tons					(7) (2 + 3 + 4)/6 (%)	(7) Yield (tons/ha) in each year	
	(2) Modern variety effect	(3) Fertilizer effect	(4) Irrigation effect	(5) Other factors (residual)	(6) Total growth in output		1965	1980
Burma	647	353	685	167	1,852	91	1.7	2.8
Bangladesh	420	1,284	1,091	2,759	5,554	50	1.7	2.0
China	13,231	11,507	16,153	9,609	50,500	81	3.0	4.1
India	7,998	10,867	11,209	5,078	35,152	86	1.3	2.0
Indonesia	3,162	2,680	2,773	4,998	13,613	63	1.8	3.3
Philippines	849	1,009	801	615	3,274	81	1.3	2.2
Sri Lanka	241	215	262	316	1,034	69	1.8	2.6
Thailand	822	682	865	4,031	6,400	37	1.8	1.9
Total (above)	**27,370**	**28,597**	**33,839**	**27,573**	**117,379**	**77**		

Source: Herdt and Capule (1983). Yields are from FAO (2014).

small shops), Thailand (power tillers; see Wattanutchariya 1983), and the Philippines (Mikkelsen and Langam 1983).

Nigeria has particularly lagged behind in witnessing any such adaptations, perhaps because of the general lack historically of comparable investments in the development and diffusion of improved varieties and irrigation technologies. This section describes in more detail these investment gaps, drawing on the lessons and experiences in Asia and Latin America.

Historically, returns to rice production globally have been primarily raised through advancements in technologies that increase yields. As shown in the previous chapter, rice yield has grown steadily in Asian and Latin American countries in the past several decades. In many Asian countries, the effects of modern varieties, fertilizer, and irrigation together have accounted for a significant share of total rice-production growth, often greater than 80 percent of the total output growth between 1965 and 1980 (column 7 in Table 4.6).

Improved Varieties and Agriculture Research and Development

Successful varieties have often triggered productivity growth (Traxler and Byerlee 1993). The introduction of high-yielding rice varieties in Japan was a key driver of agricultural development in the 19th century (Jirström 2005). The use of hybrid rice in China has contributed significantly to the transformation of Chinese agriculture since the 1980s (Lin 1994).

TABLE 4.7 Number of varieties released in Nigeria and Asia by National Agricultural Research Institutes and other sources

(1) Category	(2) Pre-1970s	(3) 1971–1980	(4) 1981–1990	(5) 1991–1999	(6) 2000–2012	(7) Total	(8) Number per million ha in 1999
Nigeria							
NARI	1	5	11	0	0	17	10
IRRI, IITA, WARDA	1	5	4	6	13	29	18
Foreign	10	3	3	2	0	18	10
Total	*12*	*13*	*18*	*8*	*13*	*64*	*38*
South and Southeast Asia							
NARI	471	338	588	421		1,818[a]	18[a]
IRRI	62	71	75	14		222[a]	2[a]
Total	*533*	*409*	*663*	*435*		*2,040*[a]	*20*[a]

Source: South and Southeast Asia: Author's estimates based on Tables 5.3 and 5.5 of Hossain et al. (2003). Nigeria: Author's modifications based on Takeshima (2014).

Note: IITA = International Institute of Tropical Agriculture. IRRI = International Rice Research Institute. NARI = National Agricultural Research Institute. WARDA = West Africa Rice Development Association (now Africa Rice Center). Blank spaces indicate information was not available. [a]Based on figures up to 1999.

In many Asian countries, substantial public-sector R&D for new varieties was in existence before 1980 (Evenson 1977; Barker, Herdt, and Rose 1985). This is in contrast to Nigeria, where domestic rice research still primarily focuses on selections and transfers of imported varieties. Up to 1999, South and Southeast Asia released 18 improved varieties developed by national agricultural research institutes (NARIs) per 1 million ha of rice area. The corresponding figure for Nigeria is only about half that: 10 per 1 million ha (column 8 in Table 4.7).

Many NARI-bred varieties have been widely adopted in Asia (Hossain et al. 2003). Rice-production ecologies and preferences vary across countries, and NARIs have played an important role in successfully developing and releasing varieties suitable for local production environments. Countries such as Indonesia invested in R&D to develop varieties with superior grain qualities suitable for local milling sector and taste preferences (Unnevehr 1986). In contrast, most major rice varieties in Nigeria are of foreign origin, except the old FARO 15, which was developed in 1974.

The success of NARI R&D in Asian countries can be attributed to the size of funding, quality of human capital, and decentralization of breeding. Countries in South Asia, Southeast Asia, and Latin America had already been investing substantially in rice R&D since the 1970s, and these countries increased rice

R&D investments in the 1990s (columns 2 and 3 in Table D.3). While Nigeria spent only US$0.3–0.5 per hectare of rice area in 1998 (constant 2010 US$, purchasing power parity [PPP] adjusted)(column 4), by 1974 many Asian countries had already been spending a similar amount or more on research per hectare of rice grown.

In many Asian countries, the rice R&D system was decentralized, which is important for crops like rice whose production environment is diverse. By the 1930s, prefectural governments in Japan had become the major funders of rice R&D (Hayami and Yamada 1998). In Thailand, breeding was conducted at a provincial level as early as the 1980s (Sarkarung, Somrith, and Chitrakorn 2000). In Sri Lanka, rice is bred in four domestic stations, although the total rice area is less than half that of Nigeria (Wang et al. 2012, 96). India already had breeding stations in several states in the 1970s (De Datta 1981, 191).

Given the experiences of Latin America and Asia, Nigeria will need to increase its own R&D spending on rice if it is to boost domestic rice production in the future. Agricultural R&D was actually higher for Nigeria in the 1970s and early 1980s than at any time since (Roseboom et al. 1994; Beintema and Ayoola 2004; Flaherty et al. 2010). This situation was a common one across Africa in general: R&D for rice as a share of rice gross domestic product (GDP) peaked during the same period (Judd et al. 1986; Lipton 1988). This coincided with steady rice yield increases in Nigeria up until the mid-1980s, when yields were similar to those in Bangladesh, India, and Thailand—and even higher than those in Brazil (Table 3.1 in Chapter 3).

Domestic rice R&D is particularly important for Nigeria given its unique production environments. Compared to Sahelian West Africa, which has production environments closer to those in Asia (Dalton and Guei 2003), adaptability of imported Asian varieties is lower in Nigeria because tropical agroclimatic conditions are more diverse, and the more numerous and more diverse insects and diseases cause more severe crop damage (De Datta 1981, 182). In tropical West Africa, returns from R&D may be higher in Nigeria, where lowland ecology accounts for a significant share of rice area, than in Guinea or Côte d'Ivoire, where much of the rice area is upland ecology (Dalton and Guei 2003, Table 6.1).[4]

4 Raising yield in upland rice ecology has been challenging. Even in Brazil and Indonesia, where national average yield has risen to 5 tons/ha, upland rice yield had remained below 2 tons until recently (Bierlen, Wailes, and Crammer 1997; Jatileksono 1998), despite substantial upland rice research by the Brazilian Corporation of Agricultural Research (Empresa Brasileira de Pesquisa Agropecuária, EMBRAPA) in Brazil (Pardey et al. 2006). This may partly explain why significant NARI variety development has not increased rice yield in these countries.

In Nigeria, R&D for upland rice can bring benefits for marginal environments, for which many of the varieties developed by New Rice for Africa have been intended. However, in terms of increasing domestic rice production, the potential may not be as great as in rainfed lowland and irrigated ecologies. To achieve significant increases in output, the substantial focus of domestic R&D should be on irrigated and lowland ecologies.

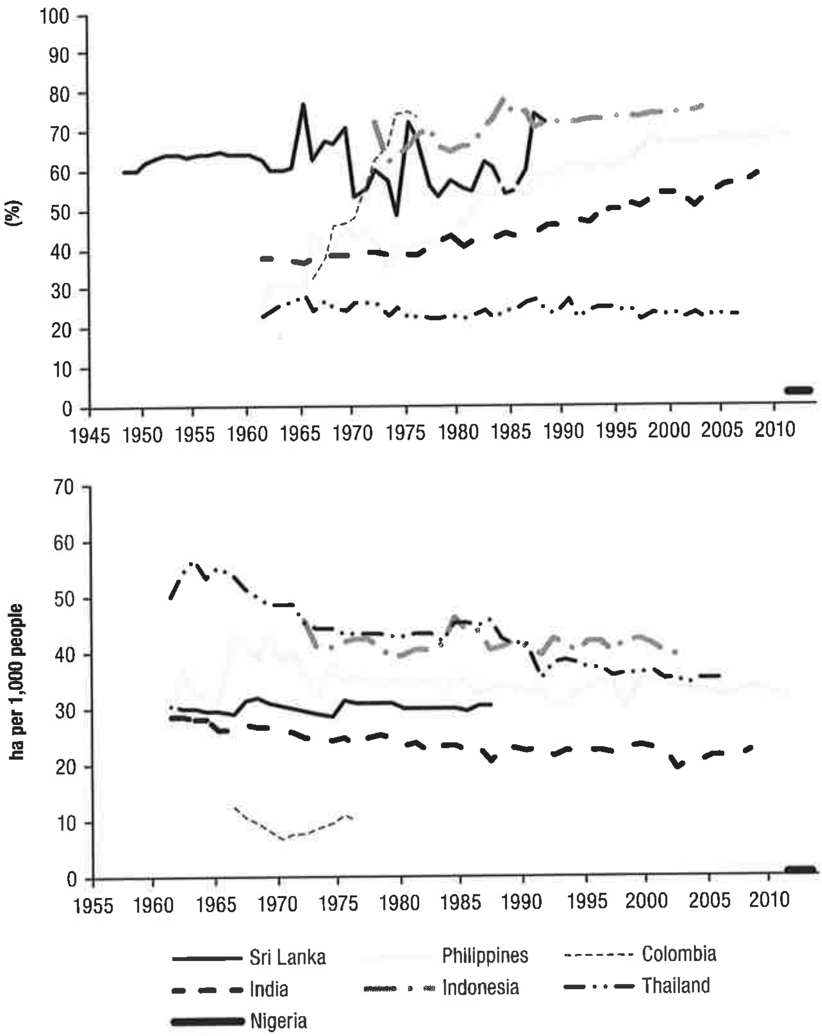
Irrigation

The extent of rice irrigation in Nigeria is far below the historical levels in Asia or Latin America (Figure 4.2). Investment in public irrigation infrastructure, prior to the Green Revolution in Asia, for example, was considered to be more cost effective in the long run than some other measures such as price support policies (Hayami, Brennan, and Barker 1977; Rosegrant, Kasryno, and Perez 1998). Asia and Latin America (Colombia) invested relatively more in public irrigation per unit of arable land than Nigeria (column 3 in Table 4.8). While Nigeria invested US$8–23 per hectare (2010 US$, PPP) between the 1970s and 2000s, other countries were already investing several times more between the 1960s and 1980s. In particular, investments have declined sharply in Nigeria since 1990. Given that the rice area expanded at the same time, irrigation investment per rice area dropped to only a fraction of the levels prevailing in the 1970s and 1980s (column 4).

It is important to note that, while the investments per rice area in Nigeria have been comparable to or even higher than other countries, the stock of irrigation infrastructure is likely to be much lower, as suggested in Figure 4.2. The cost per hectare of developing irrigation schemes in Africa south of the Sahara is similar to that in Asia. If successful irrigation schemes in SSA are considered (Inocencio et al. 2007), Nigeria will not only have to increase investments in public irrigation schemes but also focus on locations with a high probability of success. Operations and maintenance (O&M) may also need to be financed largely through public resources by means of irrigation subsidies, as was done in Asia as well as in developed countries, including the United States (Gupta, Miranda, and Parry 1995).

In Asia and Latin America, the private sector was also heavily involved in investments in rice irrigation, including communal systems in Japan, the Philippines (Barker et al. 1985, 101), Malaysia (Short and Jackson 1971), Nepal (Small et al. 1986), and Sri Lanka (Chambers 1980). These systems were usually cheaper than government systems (Kikuchi, Dozina, and Hayami 1978) and were developed by mobilizing community resources or by landlords (Hayami and Kikuchi 2000, 176). In many cases, farmers were able to develop effective

FIGURE 4.2 Percent of area irrigated and irrigated area per 1,000 people



Source: Various. Sri Lanka = Inferred from Figure 11.3 of Wijayaratna and Hemakeerthi (1992) and Aluwihare and Kikuchi (1991); India = Thakkar (1999) and World Bank (1998). Indonesia = World Rice Statistics (WRS) by IRRI. WRS are also used to supplement aforementioned studies whenever possible. Philippines = Kikuchi, Dozina, and Hayami (1978). Colombia = Chandler (1979).

Note: IRRI = International Rice Research Institute.

TABLE 4.8 Annual investment in irrigation in selected countries and Nigeria

(1) Country	(2) Average annual public investment in irrigation (2010 US$million/year, PPP adjusted)						(3) Average annual public investment in irrigation per arable land (2010 US$/ha, PPP adjusted)					(4) Average annual public investment in irrigation per rice area (2010 US$/ha, PPP)				
Periods	1950–1959	1960–1969	1970–1979	1980–1989	1990–1999	2000s	1960–1969	1970–1979	1980–1989	1990–1999	2000s	1960–1969	1970–1979	1980–1989	1990–1999	2000s
Sri Lanka	229	186	332	818			249	381	924			356	464	1,013		
Philippines		36	275	711			7	58	134			11	80	207		
India	2,060	3,338	5,591	8,493	11,879		21	35	52	73		93	145	208	278	
Indonesia			1,014	1,972				56	104				122	207		
Colombia[a]		99	57	127			28	16	34			323	168	304		
Nigeria[b]			647	647	246	447		23	23	8	13		1,146	1,146	120	193

Source: Author's estimates based on various sources: Aluwihare and Kikuchi (1991) for Sri Lanka; for Nigeria, Foster and Pushak (2011) in 2001–2006, Pagiola et al. (2002) for 1990s, Pradhan (1993, 21) for 1970s and 1980s; Kikuchi, Dozina, and Hayami (1978) for the Philippines; Thakkar (1999) for India; Rosegrant and Pasandaran (1993) for Indonesia; Dinar and Keck (1997) for Colombia.

Note: PPP = purchasing power parity. Annual investment in irrigation includes new construction, rehabilitation, operation and maintenance, and other small uncategorized expenditure. Not all studies, however, provide such disaggregation, and categorization may vary across countries. Blank cells indicate missing data, not lack of investment. [a] For Colombia, approximate numbers are assessed from Figure 2 of Dinar and Keck (1997) due to the lack of access to the original data. [b] For Nigeria, Pradhan (1993, 21) mentioned only that Nigeria spent $3 billion in the two decades up to the early 1990s. Assuming $150 million was spent each year for two decades, converting each year's figure into 2010 US$, as well as making PPP adjustment, I arrived at the figure of $647 million/year (2000 US$, PPP) for the 1970s and 1980s.

community management of common resources that avoided the tragedy of commons (Hayami and Kikuchi 2000, 134; Feeny et al. 1990; Ostrom 1990, 1992; Baland and Platteau 1996).[5]

In early 20th-century Colombia, irrigation was introduced and facilities constructed by private entrepreneurs (Leurquin 1967, 227). In parts of Nigeria, similar river diversion structures have been constructed and used for rice irrigation on *fadama* areas, where farmers divert river flow using sand embankments.[6] Such areas are small, however, and yields are relatively low. The low private irrigation investments in Nigeria indicate that technologies and economic conditions are unconducive for irrigated rice production, and investment in public irrigation schemes will need to be combined with the development of sufficiently superior varieties and profitable production environments.

In particular, expansion of rice irrigation in the past has largely been to provide supplementary irrigation in the rainy season rather than in the dry season (columns 3 and 4 in Table 4.9), as rice requires substantial amounts of water. This was led by the development of good varieties with resistance to pests and diseases that are more prevalent in the wet season than dry season. This pattern of rice varietal development and irrigation expansion in Asia may have important implications for Nigeria as well.

Price Policies: Output Price Control, Input Subsidies

In addition to investments in technology, price policies were widely adopted instruments in Asia during the Green Revolution (Djurfeldt and Jirström 2005). Many Asian countries have enjoyed a higher rice price relative to fertilizer price than West African countries (Otsuka and Kalirajan 2006). If Asian governments have succeeded in achieving such favorable prices for producers, such price policies might have been important in realizing higher yield growth.

Historical patterns in Nigeria, however, contradict such a theory. Table 4.10 shows nominal rates of assistance (NRAs) for rice in selected West African countries. Table 4.11 shows the ratio of fertilizer prices to paddy prices in selected countries, another important indicator of the level of agricultural protection (Judd, Boyce, and Evenson 1986). As in Table 4.10, while many other West African countries have experienced negative NRA in much of the last several decades (except rice in Ghana between

5 The "tragedy of the commons" (Hardin 1968) refers to the situation where common-pool resources with finite reserves become exhausted by rational individual users because of the difficulty in controlling their uses.

6 Based on author's fieldwork in July 2013.

TABLE 4.9 Share of irrigated area among all rice areas in selected countries

(1) Country	(2) Periods	Irrigated area (1,000 ha) under each regime: (3) DS (dry season)	(4) WS (wet season—supplementary)	(5) Rainfed	(6) % of irrigated rice area among all rice area	(7) Hectares of irrigated area per 1,000 people
Bangladesh	1970–1974	980	590	8,200	16	23
Burma	1970–1974	50	800	4,140	17	31
	1979	115	780	4,422	17	
Philippines	1970–1974	480	1,430	1,580	55	51
India	1970–1974	1,890	13,120	22,650	40	26
Indonesia	1970–1974	1,610	2,370	4,500	47	32
	1979	1,920	3,274	3,010	63	37
Thailand	1970–1974	140	630	6,260	11	20
	1979	320	866	7,491	14	26
Nepal	1970–1974	0	190	1,020	16	15
	1979	0	261	1,001	21	19
Malaysia	1970–1974	270	270	170	76	47
Vietnam	1970–1974	140	270	2,310	15	9
Sri Lanka	1970–1974	150	220	230	62	28
	1979	182	294	284	63	32
Nigeria	2010–2011	23	89	2,400	4	0.7

Source: For Asian countries, author's compilations from Chandler (1979) and Barker, Herdt, and Rose (1985). Nigerian data are from Takeshima and Edeh (2013). Population figures are taken from FAO (2014) for corresponding periods.

TABLE 4.10 Growth in nominal rate of assistance to agriculture, selected West African countries, 1960–2004

	1960–1964	1975–1979	1980–1984	1990–1994	2000–2004
Cameroon	−2.9	−14.4		−1.1	−0.1
Côte d'Ivoire	−23.5	−30.8		−19.5	−24.5
Rice		−25.0	−10.0		
Ghana	−9.0	−25.6		−1.7	−1.4
Rice		+13.0	+29.0		
Nigeria	+20.7	+6.3		+3.9	−5.4
Senegal	−9.3	−22.7		+5.6	−7.5

Source: Krueger, Schiff, and Valdès (1988); Anderson (2009); Dupraz and Postolle (2013).

Note: Blank spaces indicate that information is not available. While rates can vary if the black market exchange rate is different from the official rate, relative levels of NRA for rice during 1980–1986 were similar among countries in Asia and Africa regardless of the types of rates used for calculation (assessed from Taylor and Phillips 1991, Appendix).

TABLE 4.11 Urea-to-paddy (kg) price ratio in selected countries and Nigeria

Years	Bangladesh	Colombia	India	Indonesia	Philippines	Sri Lanka	Thailand	Côte d'Ivoire	Benin	Nigeria
1966–1970		2.1	2.9		3.2	1.4		2.7		
1971–1975	1.6	4.9	2.7	3.4	1.6	1.7		3.4	2.6	
1976–1980	2.0	3.3	2.6	1.8	3.8	1.4	3.0	2.2	1.9	1.5
1981–1985	2.4	3.3	2.6	1.3	4.1	1.7	5.1	3.3	1.5	1.6
1986–1990	1.9	1.6	2.4	1.5	2.4	1.9	2.8	2.9	1.7	1.0
1991–1995	1.9	2.7	1.6	1.5	2.4	2.6	3.8	4.2	2.2	1.3
1996–2000	2.0	1.7	1.6	1.8	1.9	1.5	2.7	3.7		1.7
2001–2002	2.0	2.2	1.7	1.7	2.2	1.6	2.9			

Source: Author's compilation based on Estudillo and Otsuka (2012), World Rice Statistics (farm harvest price of paddy) (IRRI 2014), and FAOSTAT (urea price) (FAO 2014).

Note: FAOSTAT = Statistical database of the Food and Agriculture Organization of the United Nations.

1975 and 1984), Nigeria has actually enjoyed a positive NRA except during the 2000s. These conditions are likely to hold for rice because Nigeria has been unique in the West African region, as well as the rest of Africa south of the Sahara, in terms of the level of rice import restrictions (tariffs, banning, etc.) (Akande 2001) and fertilizer subsidies.

From the late 1970s to the early 1980s, there was either a tariff of 10–20 percent or various import restrictions in Nigeria, and between 1985 through 1995, rice imports were banned altogether. After the ban was lifted in 1995, tariff rates remained between 50 to 100 percent in much of the 1990s, higher than other West African countries and the rest of SSA (Akande 2001). For example, the tariff or import tax on rice in the 1990s was 10–30 percent in Madagascar (Fafchamps and Minten 1999), 5–13 percent in Côte d'Ivoire (Abbott 2007, Appendix Table 19), and 38 percent in Cameroon, between 1996 and 2008 (Molua 2010).

While the implementation of these policies has not been effective, as shown in Chapter 7, these restrictive policies still succeeded in keeping rice prices higher in Nigeria than in other countries in Asia or West Africa. For example, the farm-harvest paddy rice price in Nigeria was in the range US$290–450 per ton (current US$/ton using parallel market exchange rates) between 1970 and 1990 (column 13 in Table D.4 in Appendix D). These prices were substantially higher than those in Côte d'Ivoire and Benin, for example (columns 9 and 10 in Table D.4). As a result, the fertilizer-to-paddy price ratio in Nigeria between 1976 and 2000 was more comparable with that in some Asian countries than that in Côte d'Ivoire

(Table 4.11). This is also consistent with the recent findings in Nigeria that fertilizer subsidies do not lead to a significant reduction in rice prices (Takeshima and Liverpool-Tasie 2015). The economic environment for rice production in terms of the fertilizer-to-paddy price ratio was therefore fairly favorable in Nigeria during this period.

For many low-income countries like Nigeria, price policies will affect production growth only if they are complemented by technical progress (Mellor 1978). In other words, technological advancement and investments in public irrigation infrastructure are more cost effective in the long run than price support policies, as has been shown in Asia (Hayami, Brennan, and Barker 1977; Rosegrant, Kasryno, and Perez 1998). On the other hand, from Asia's experience, the combination of input subsidies with investments in R&D and irrigation have been shown to result in higher yield growth (Rashid et al. 2013). These sets of evidence suggest that, in contrast to other countries in Asia, price policies have been inefficient in raising rice production and productivity in Nigeria primarily because of insufficient complementary investments in agricultural R&D and irrigation.

Conclusion

Rice production in Nigeria is characterized by low levels of improved technology adoption, especially for the superior-quality and high-yield seed varieties and irrigation. On the other hand, the diffusion in the use of other modern inputs such as fertilizer has been high at times whenever the paddy-to-fertilizer price ratio has increased, either due to fertilizer subsidies or higher rice import tariffs. Despite such incentives, the profitability of rice production has generally remained low, particularly in the irrigated and rainfed lowland ecologies, which are the major rice-production systems in Nigeria. Yield is often low despite the higher intensity of modern input use.

Evidently, higher rice prices are not sufficient by themselves to stimulate output growth for domestic rice production in Nigeria. Based on nationwide panel survey data, the price elasticity of both rice production and irrigated rice areas is low. A 1 percent increase in the price of paddy at the farmgate leads to only a small increase in rice production and has almost no effect on the irrigated rice area. This is consistent with the technological backwardness of rice production in Nigeria and results from historically low investments in rice R&D and irrigation compared to other developing countries in Asia and Latin America.

Key technologies, such as superior-quality seed varieties and irrigation and their continuous improvement, are critically important for transforming paddy production, as evident in the contrasts between Nigeria and other developing countries. Price policies are likely to be more effective in stimulating an aggregate supply response if there is greater use of improved technologies and better functioning of markets and institutions (Kherallah et al. 2002). In Asia and Latin America, governments have played a big role in investing in such technologies. Nigeria will also need to substantially increase these types of investments if it is going to successfully transform its paddy production sector.