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IFPRI Discussion Paper 01301

November 2013

Assessing the Potential and Policy Alternatives for Achieving Rice Competitiveness and Growth in Nigeria

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Contents

Acknowledgments vi

Abstract vii

1. Introduction 1
2. The Challenge of Rising Demand and Imports 4
3. Structure and Performance of the Rice Value Chain 13
4. Analyzing the Potential to Increase Competitiveness 25
5. Weighing the Future Economic Costs and Benefits of Alternative Policies 36
6. Conclusion: Policy Implications and Discussion 46

Appendix A: Supplementary Tables 50

Appendix B: Estimation Methods for Biophysical Analysis 53

Appendix C: Cluster Analysis 57

References 60

Tables

1.1 Volume and growth of milled rice supply in Nigeria (million metric tons) 1

2.1 Rice production shares in West Africa 4

2.2 Average rice yields and growth, 1990–2011 5

2.3 Rank of commodity by per capita consumption and expenditure 5

2.4 Rice consumption and production, 2011 6

2.5 Average budget share across commodities 6

2.6 Rice-consuming population share by zone 7

2.7 Marginal budget shares and income elasticity of demand 8

2.8 Income elasticity of demand across countries/regions 9

2.9 Summary of urban rice prices in Enugu 12

3.1 Dominant rice production systems in Nigeria 13

3.2 Paddy rice area, production, and yield in Nigeria, three-year averages, 2007–11 15

3.3 Comparison of production costs, yields, and profit margins 22

3.4 Disadvantages and advantages of small- to medium-scale and large-scale millers 23

4.1 Rice production potential: A suitability assessment 26

4.2 Simulation scenarios and assumptions 26

4.3 Irrigation expansion assumptions 27

4.4 Rice yields under different technology inputs 27

4.5 Rice outputs under different technology inputs (million metric tons) 28

4.6 Characteristics of major rice producer types 29

4.7 Key parameters affecting profitability of small- versus large-scale rice milling 31

5.1 Assumptions and targets applied in the Nigerian economywide multimarket model simulations 37

A.1 Rice imports and exports by country of origin to Nigeria (various years) 50

A.2 Rice marketing channels: Actors, roles and functions, and key constraints 51

A.3 List of agricultural sectors (products) included in economywide multimarket model 52

B.1 Example of baseline, simulated yield, and output estimation 56

C.1 Variables used in cluster analysis 58

Figures

1.1 Trends in rice production, imports, and population, 1990-2012 2
2.1 Aggregate consumption of rice, compared with other major staples, 2011 6
2.2 Rice imports by and reported exports to Nigeria 10
2.3 Rice imports and exports by Benin, and reported exports to Benin 10
2.4 Nigeria: Domestic and border prices of rice, 2005–2012 11
3.1 Rice value chain in Nigeria 17
3.2 Comparison of rice value chains between Nigeria and Thailand, 2009 20
3.3 Price structures of the rice value chain in selected countries 21
4.1 Evolution of modern rice mills, yields, and net exports in India 32
5.1 Change in total rice production under alternative scenarios (% change from base year) 38
5.2 Change in cultivated rice area under alternative scenarios (% change from base year) 39
5.3 Ratio of rice imports to consumption under alternative scenarios (%) 40
5.4 Change in rice demand under alternative scenarios (% change from base year) 40
5.5 Rice production and demand under different tariff rates 41
5.6 Yield and cultivated area of rice under different tariff rates 41
5.7 Changes in real GDP and food price index under different tariff rates 42
5.8 Changes in rural and urban per capita real income under alternative scenarios 43
5.9 Changes in relative rice prices under alternative scenarios (% change from base year) 44
B.1 Rice suitability 53

Box

3.1 The experience of Olam in Nigeria 24

ACKNOWLEDGMENTS

The authors wish to acknowledge the valuable contributions of various Nigerian stakeholders during the presentation of this study's results and key findings at various venues. In particular, special thanks got to Dr Akin Adesina, the Honorable Minister of the Federal Government's Ministry of Agriculture and Rural Development, and his staff for sharing the government's policy perspectives and future vision for the rice sector in Nigeria during a presentation of preliminary results in September 2012. Additionally, comments shared by Professor Osiname, team leader of the ATA Rice Value Chain team, in reviewing an earlier draft of this paper, together with stakeholder feedback obtained during a presentation of preliminary results at a workshop in Abuja in November, 2012 and a Seminar at the Agricultural University of Benue State in Makurdi in April, 2013, proved very valuable. Finally, the analysis in this paper would not have been possible without relying heavily on the contributions of the many other researchers and development specialists who have surveyed and studied the rice value chain in Nigeria, West Africa and Asia – and the financial support of the United States Agency for International Development.

ABSTRACT

The principal objective of this paper is to review and assess the policy implications and potential for Nigeria to transform its domestic rice sector and become more competitive with imports in order to ultimately displace them over time. Since 2011, the Nigerian government embarked on an ambitious plan to make the country self-sufficient in rice production by 2015 under its Agricultural Transformation Agenda (ATA). This was in response to the perceived threat of larger volumes of milled rice being imported into Nigeria every year with an import bill that exceeds US$2 Billion. Aside from rising global prices, domestic demand for rice has been growing at a rapid pace due to changing consumer preferences, rising incomes, and growing urban populations. To achieve its goal of rice self-sufficiency by 2015, the Nigerian government has introduced a number of key policies and investment strategies to reduce imports and increase the competitiveness of local rice. This is being done through a combination of import restrictions, input policy and institutional reforms, and direct investments all long the rice value chain.

More specifically, in order to assess the feasibility and policy alternatives for transforming the domestic rice economy in Nigeria, the paper seeks to answer the following questions: Are the policies being considered by the current ATA sufficient? Will they ultimately lead to displacing imports? What are the alternatives given this knowledge? Aside from a comprehensive review of the rice value chain in Nigeria and its potential competitiveness with imports, an economy-wide simulation model of the rice economy is used to answer some of these broad policy questions. This includes introducing a range of import tariffs to assess their effectiveness in contributing to the self-sufficiency goal and implications for overall economic welfare. The hypothesis is that without alternative policy measures that address supply side issues such as improving the productivity and efficiency of the value chain, simply imposing import barriers will not succeed in switching consumer demand to local rice.

Preliminary results show that import restrictions alone will not be effective at achieving self-sufficiency in rice production. While there is a huge potential to increase the competitiveness of local rice, even this will not be sufficient to displace imports in the short and medium term. This is especially true so long local varieties cannot compete on quality and post-harvest processes remain inadequate for milling, packaging, and branding. While meeting the demand for higher quality premium rice in the short run is only feasible through the use of large scale millers as the government is already promoting, it will not lead to job creation and wealth in rural areas nor will it help poorer consumers who have to spend a higher proportion of their income on food.

Keywords: rice self-sufficiency, import restrictions, rice value chain, competitiveness

1. INTRODUCTION

The Nigerian government has embarked on an ambitious plan to make the country self-sufficient in rice production by 2015 under its current Agricultural Transformation Agenda, or ATA (Adesina 2012). This initiative is in response to the perceived threat of larger volumes of milled rice imports into Nigeria since the 1990s, potentially displacing local production. As Table 1.1 shows, local production has not been able to meet a growing appetite for rice consumption, the share of domestic production having declined from 75 percent in the 1990s to 53 percent in the most recent period. By 2010, the import bill was close to US$2.2 billion.[1] As elsewhere in West Africa, the rice import bill rose sharply following the 2008 global food price hikes, and Nigeria, like many other countries, was left feeling vulnerable to future shocks in global rice prices.

Table 1.1 Volume and growth of milled rice supply in Nigeria (million metric tons)

Category	1990–1999	2000–2009	2010–2012
Production	1.8	2.1	2.7
Imports	0.6	1.7	2.4
Total	2.4	3.9	5.1
Production share (%)	75.5	55.1	53.0

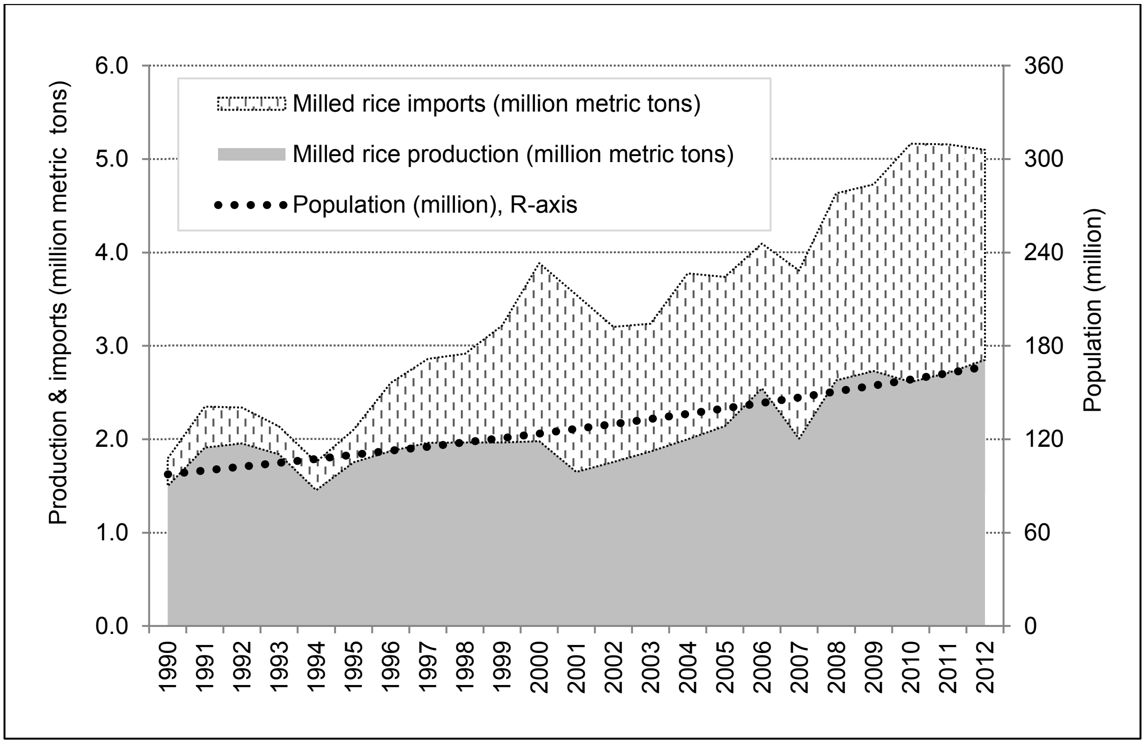
Source: USDA international database (USDA–ERS 2012).

Despite rising global prices, domestic demand for rice has been growing at a rapid pace in Africa in general due to changing consumer preferences, rising incomes, and growing urban populations (Nwanze et al. 2006). As a result, in no African country has production been able to keep pace with demand, and countries instead have come to rely on imports to make up the difference. As Figure 1.1 shows, rice imports have generally grown faster than both production and population, with the latter two growing at about the same pace.[2] The growing dependency on rice imports threatens to deplete a country's scarce foreign currency reserves, increases its vulnerability to global price shocks, and raises overall concerns about food insecurity. Consequently, many countries have been motivated to introduce initiatives designed to promote domestic rice production in order to achieve self-sufficiency through import restrictions and investments to improve product output and quality. Nigeria has embarked on such a path.

[1] All dollar amounts are in US dollars.

[2] While it is possible that some imports may pass through to neighboring countries such as Niger, Chad and Cameroon, this is difficult to confirm given scanty data on informal cross border trade. But we expect these shares to be small given the sheer size of the Nigerian market relative to these other countries.

Figure 1.1 Trends in rice production, imports, and population, 1990–2012



Sources: USDA international database (USDA–ERS 2012) for production and imports; FAOSTAT (FAO 2012) for population.

To promote domestic production and displace imports, the Nigerian government has introduced a number of key policies and investment strategies. At the macro level, rice import tariffs are being increased to the point of a complete embargo by 2015, when the goal of rice self-sufficiency is supposed to be met. The tariff increases are intended to protect the domestic rice sector while it undergoes improvements in paddy production, processing, and marketing with the support of public-sector reforms and investments. The reforms include deregulating seed and fertilizer markets and setting up private-sector marketing corporations to help coordinate the market and set grades and standards. Innovative financing mechanisms for supplying credit are also being pursued while physical investments are being made to establish staple crop processing zones (SCPZ) that are intended to encourage the clustering of food processing industries in proximity to raw materials and end markets.

The rice self-sufficiency goal is not new to Nigeria. There have been other, similar initiatives in the past. Two of the most recent are the Presidential Initiative on Rice introduced in 1999 and the National Program for Food Security launched in 2001 (Akaeze 2010). Each of these initiatives included a policy of import barriers. Unfortunately, the effects of the price incentives that followed did not lead to any significant supply response, nor did public investments to improve yields, such as irrigation systems in river basins, development and dissemination of high-yielding seed varieties, and improved access to fertilizer. In fact, the supply response elasticity to price incentives produced by import restrictions has been found to be negligible. Estimates by Rahji and Adewumi (2008), for example, are very low (0.07) while those by Ayanwale et al, (2011) are found to be statistically insignificant. Part of the problem is that local rice is not easily substitutable with imports due to their marked difference in quality. Another part could be a result of the reputation of policy inconsistencies over time, oscillating from zero tariffs in one period to very high tariffs in another to an outright ban on imports, which discourages long-term investments (Ezedinma 2005). Finally, the inherent *Dutch disease* syndrome of being a major oil exporter has also undermined investments in the agricultural sector more generally over time (Pinto 1987).

The potential for Nigeria to succeed in its quest to become self-sufficient in rice will depend a lot on how well the government can maintain its policies and investments over the long term. Certainly, there is a high level of political will and leadership to change attitudes toward transforming the rice sector and the rural economy more broadly. These factors are important in facing the many skeptics among the general population and among direct beneficiaries of the strategy, given the record of well-intentioned but failed efforts in the past. Another positive sign is the unprecedented attention being given to improving the postharvest segment of the rice value chain in order to improve quality and compete more effectively with imports (Adesina 2012). The importance of focusing attention on improving both the quality and marketing of domestic rice has been shown elsewhere in West Africa (in the example of Senegal) to be even more important to begin with than increasing paddy production (Demont et al. 2013). In other words, simply growing more rice paddy will not guarantee the displacement of imports so long as the processing sector is unable to absorb the increase nor improve product quality. The real question that remains is whether these positive signs and ongoing efforts are going to be sufficient for Nigeria to be able to compete more effectively with imports over time.

The principal objective of this paper is to review and assess the policy alternatives and potential for Nigeria to transform its domestic rice sector and become more competitive with imports in order to ultimately displace them over time. Two key strategies that have been adopted by the government under the ATA initiative are examined with regard to their potential to succeed and their long-run welfare implications for contributing to this self-sufficiency goal. The first is the introduction of import tariffs in order to make domestic rice more competitive on price alone. The second concerns expanding paddy production and processing of premium-quality rice in order to adequately replace imports over the long run. In the process, a number of key policy questions arise, including but not limited to the following: Is there potential for domestic rice production to grow and achieve self-sufficiency in the short to medium term? Is there potential to the improve quality and competitiveness of the final domestic rice product in domestic markets? What is the most efficient way to take advantage of this potential for both production and processing? Are there differential abilities and efficiencies among existing mill types (small to large) for improving quality and meeting demand? Are there lessons that can be drawn from elsewhere in West Africa and Asia? Are the policies being considered by the current ATA sufficient? Will they ultimately lead to displacing imports? What are the alternatives given this knowledge? We discuss these issues in this paper.

The paper is organized as follows. We begin by examining the challenge of rising demand and imports. This is followed by an overview of the current structure and performance of the rice value chain in order to highlight some of the key constraints and opportunities for improvement. Next, we assess in more detail the potential to rapidly increase productivity, output, and quality along the value chain.[3] Based on our findings, we introduce this potential to an economywide simulation of the rice economy in order to assess the prospects of achieving the rice self-sufficiency goal. A range of import tariffs are also introduced to assess their effectiveness in contributing to this goal and their implications for overall economic welfare. The hypothesis is that without alternative policy measures that address supply-side issues, such as improving the productivity and efficiency of the value chain, simply imposing import barriers will not succeed in making Nigeria self-sufficient in rice.

[3] It is worth noting on the outset that the authors found it especially challenging to obtain more recent and accurate data on rice production systems and processing in Nigeria. Consequently, much of the data and analysis undertaken for this study had to rely on a combination of recent data sources that required the authors to carefully cross check and validate any values across them. Sources were obtained at both the national level (e.g. either directly from national institutions such as the National Bureau of Statistics or from own field visits) and international sources (e.g. from USDA's international commodity database and United Nation's COMTRADE and FAOSTAT databases). This was in addition to an extensive review of any past literature and data which are referenced in each section of the paper accordingly.

2. THE CHALLENGE OF RISING DEMAND AND IMPORTS[4]

As demand for rice has risen in Nigeria, it is clear that production has failed to keep pace while the gap has been bridged by growing imports, as shown in the previous section. Rising consumer preference for rice has increased demand at a faster rate than population growth. In fact, as Table 2.1 shows, per capita production has remained stagnant at about 28 kilograms (kg) since 1990 while per capita consumption has increased from about 18 kg to about 34 kg in the same period. This is in sharp contrast to Mali, Ghana, and Senegal, where per capita production has doubled or even tripled over the same period. As a result, while Nigeria contributes the most to total production in the region, its share has declined by 10 percentage points since the early 1990s, from 47.7 to 37.5 percent. Aside from Nigeria, the other major rice producers in the region are Mali, Guinea, Sierra Leone, Côte d'Ivoire, Senegal, and Ghana. Including Nigeria, these seven countries account for about 90 percent of total production in the region (Table 2.1).

Table 2.1 Rice production shares in West Africa

Country	1990–1995	1995–2000	2000–2005	2005–2010	2010–2011
		Production share (%)			
Nigeria	47.7	46.8	43.1	39.2	37.5
Mali	6.9	9.4	11.4	14.8	16.7
Guinea	13.7	15.0	15.7	14.6	12.4
Sierra Leone	7.5	4.8	5.9	8.4	8.7
Côte d'Ivoire	11.2	9.4	9.0	7.1	5.9
Senegal	2.9	2.5	2.9	3.6	4.2
Ghana	2.4	3.1	3.6	3.2	4.0
Total	92.3	91.0	91.5	90.8	89.4
		Per capita production (kg)			
Nigeria	28	27	24	26	28
Mali	45	61	68	103	130
Guinea	124	128	132	149	148
Sierra Leone	115	82	93	150	177
Côte d'Ivoire	50	41	38	36	36
Senegal	22	19	21	31	40
Ghana	9	12	13	14	19
Total W. Africa	31	31	29	34	39

Source: Authors' calculations based on FAOSTAT (FAO 2012).

The steady increases in rice production in Mali, Senegal, and Ghana can be partially attributed to rising yields over time, reaching between 2.5 and 3.9 tons[5]/hectares (ha) in recent times, comparable to yields in South Asia a decade earlier (Table 2.2). Clearly the Nigerian rice economy has lagged behind that of these three countries and others in the region. This lag illustrates the general neglect of agriculture from previous periods of political instability and poor governance throughout the 1970s and 1980s, sometimes attributed to a Dutch disease syndrome following the oil boom that began in the 1970s (Udoh and Egwaikhide 2011). Essentially, the increase in incomes and the shift in terms of trade in favor of imports created disincentives for agricultural investments and reallocated factors of production away from it. Arguably, the Dutch disease could have been avoided if the windfall revenue from oil exports had been used to invest in agriculture (Levy 2006).

[4] This section was authored by Oluyemisi Kuku, Paul Dorosh, Mehrab Malek, and Angga Pradesha.
[5] Throughout the paper, *tons* refers to metric tons.

Table 2.2 Average rice yields and growth, 1990–2011

Country/Region	Average yields					Yield growth rates		
	1990–1995	1995–2000	2000–2005	2005–2010	2010–2011	1980–1990	1990–2000	2000–2011
Asia								
Bangladesh	2.6	3.0	3.5	4.1	4.3	2.5	2.4	2.4
India	2.7	2.8	3.0	3.2	3.4	3.2	1.1	1.8
Thailand	2.2	2.5	2.8	2.9	3.0	0.7	2.1	0.8
West Africa								
Nigeria	1.8	1.6	1.4	1.6	1.8	0.3	-3.1	3.0
Ghana	1.8	1.9	2.2	2.2	2.5	7.7	1.4	1.3
Mali	1.6	2.0	2.0	2.8	2.7	4.7	3.5	3.3
Senegal	2.3	2.4	2.5	3.1	3.9	5.2	0.2	5.0
Regional								
West Africa	1.6	1.6	1.6	1.8	2.0	1.8	-0.2	2.6
South Asia	2.7	2.9	3.1	3.4	3.6	2.8	1.4	1.9
World	3.6	3.8	4.0	4.2	4.4	2.3	1.1	1.2

Source: Authors' calculations based on FAO 2013.

With insufficient growth in production to meet domestic demand and with rice imports growing at about 11 percent per year since 1990, Nigeria is facing a real policy challenge in reversing such trends. The purpose of this section is to delve deeper into understanding this current circumstance before evaluating the country's policy options and the potential success of the ATA. We begin by examining the changing consumer demand patterns for rice over time in order to understand their characteristics and challenges for policy. Next we analyze the effects of changing supply and demand characteristics on import and domestic price trends in general in order to further highlight some of the key policy challenges facing the country.

The Growing Importance of Rice as a Food Staple

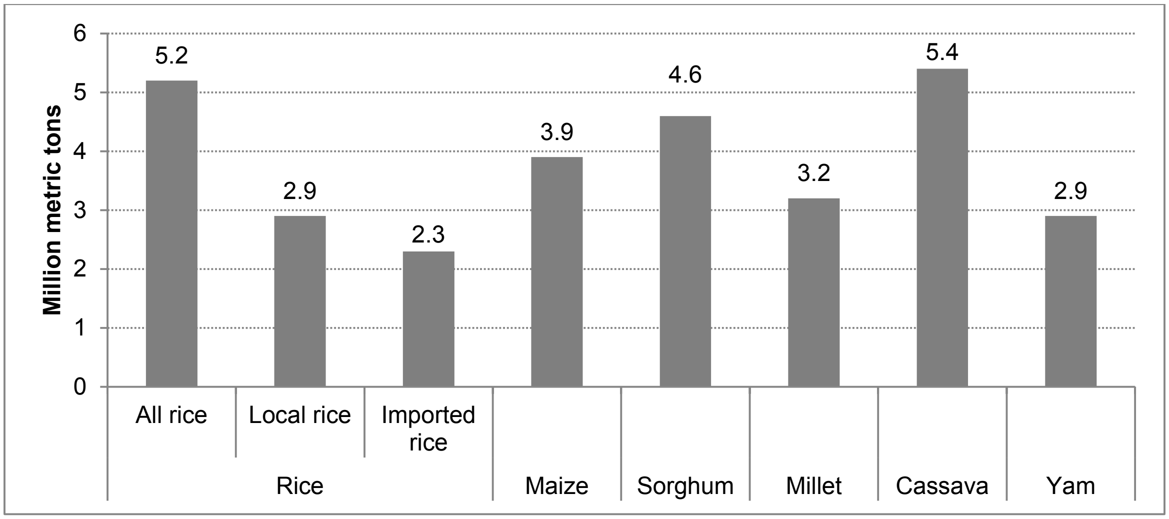
Rice has become one of the most important staples in Nigeria. The commodity now ranks first among all staple food items in terms of expenditures (Table 2.3) and second only to cassava in terms of quantity consumed (Figure 2.1). Of the 5.2 million tons of local rice consumed in 2011, only 2.7 million tons (52 percent) was produced locally, with rice imports accounting for the outstanding 2.45 million tons (47.5 percent) of rice consumed (Table 2.4). In addition, an average Nigerian household spent 6 percent of its total income on rice consumption in 2011. This average budget share was the highest among staples in this time period, and the trend was consistent for both urban and rural populations (Table 2.5). Compared with other commodities, rice is also widely consumed, with 84 percent of households reporting consuming rice at home (Table 2.6).

Table 2.3 Rank of commodity by per capita consumption and expenditure

Commodity	Annual consumption (kg/capita)	Rank by consumption quantity per capita	Annual expenditure (Nigerian naira / capita)	Rank by expenditure per capita
Rice	32.2	2	3,951	1
Rice—local	17.6		1,893	
Rice—imported	14.5		2,058	
Maize	24.1	4	1,164	4
Sorghum	28.3	3	960	5
Millet	19.8	5	786	6
Cassava	33.1	1	2,374	3
Yam	18.2	6	2,824	2

Source: Authors' calculations from Nigeria's Living Standard Measurement Study–Integrated Survey on Agriculture (Nigeria, NBS; and World Bank 2011).

Figure 2.1 Aggregate consumption of rice, compared with other major staples, 2011



Source: Nigeria's Living Standard Measurement Study–Integrated Survey on Agriculture (Nigeria, NBS; and World Bank 2011).

Table 2.4 Rice consumption and production, 2011

Commodity	Total consumption (million metric tons)	Total consumption share (%)	Total production (million metric tons)	Total production share (%)
Rice	5.20		5.16	
Rice—local	2.85	54.8	2.71	52.5
Rice—imported	2.35	45.2	2.45	47.5

Sources: Consumption data from *Nigeria's Living Standard Measurement Study–Integrated Survey on Agriculture* (Nigeria, NBS; and World Bank 2011); production data from USDA international database (USDA–ERS 2012).

Table 2.5 Average budget share across commodities

Commodity	Average budget share (%)		
	Urban	Rural	National
Rice	5.7	7	6.6
Rice—local	1.8	4.7	3.8
Rice—imported	3.8	2.4	2.8
Maize	1.2	2.7	2.2
Wheat	1.7	1.5	1.6
Sorghum/millet	1.3	5.7	4.3
Other grains	0.1	0.1	0.1
Cassava	3.2	4.8	4.3
Yam	4.6	5.3	5
Other roots	1.3	1.6	1.5
Pulses	3	3.9	3.6
Oils and fats	4.7	6.7	6.1
Fruits/vegetables	5.2	7.1	6.5
Milk	1.1	1	1
Poultry	0.9	1.1	1
Other meat	5.3	6.1	5.9
Fish	5.5	5.9	5.8
Other food	3.1	3.8	3.5
Dining out	12.8	9.3	10.4
Nonfood	39.5	26.4	30.5
Total	100	100	100

Source: Authors' calculations from Nigeria's Living Standard Measurement Study–Integrated Survey on Agriculture (Nigeria, NBS; and World Bank 2011).

Table 2.6 Rice-consuming population share by zone

Zone	Share of rice-consuming population in total population (%)	Share of imported rice–consuming population (%)
Urban	90.8	71.8
Rural	79.9	33.1
National	83.8	48.2

Source: Authors' calculations from Nigeria's Living Standard Measurement Study–Integrated Survey on Agriculture (Nigeria, NBS; and World Bank 2011).

Nigeria has a rich history of rice production and consumption, as indigenous rice species (local rice) have been grown there for more than 300 years (Akinbile 2007). Rice has over time developed into a major staple crop in the Nigerian diet, with a demand profile cutting across all regions and socioeconomic groups. There has been a steady rise in consumption of all cereals in general, and rice in particular (as previously shown in Figure 1.1). A variety of other factors, including rapid urbanization, acceleration in the population growth rate, increase in per capita income, and changes in family occupational structures, have also contributed to this increased demand (Akpokodje, Lançon, and Erenstein 2001; Akande 2002; UNEP 2005). Urbanization is a major factor in rice demand because of the lifestyle changes that it engenders, requiring foods that take less time and effort to prepare, and rice has been able to meet these conditions very satisfactorily.

While most consumers combine imported and local rice in their diets, urban households have a preference for imported rice (Table 2.6). The characteristics that have attracted so many consumers to imported rice include higher quality, defined as a higher swelling capacity; better taste; and preferred grain shape and cleanliness because it tends to be polished, nonbroken, and free from stones and other debris (Bamidele, Abayomi, and Esther 2010; Lançon et al. 2003b).

Local rice is consumed for several reasons: It is either cheaper as in the majority of rice produced or in other cases it possesses organoleptic attributes that makes it a vital component in certain local delicacies (Bamidele, Abayomi, and Esther 2010). These delicacies include *tuwo* in the north, where the local rice is preferred for its ability to absorb water and be pounded into paste, and *ofada* rice in the southwest, which is preferred for its unique aroma. For the rest of the local rice produced, it is usually treated as an inferior food due to improper processing and the presence of foreign matter (such as stones). Consequently, most consumers of local rice (particularly in urban areas) aspire to be able to afford imported rice, which is cleaner and can be utilized to produce a wide variety of sophisticated dishes (*jollof* rice and fried rice, for example).

Analysis of Marginal Budget Shares and Demand Elasticities

A major indicator of the demand for rice can be captured by how households allocate additional spending made possible by higher income—which defines the marginal budget share (MBS) of rice. The value of MBS should have additive properties; that is, the value of all extra demand following a rise in income must exactly equal the value of the extra income (Deaton and Muellbauer 1980). In keeping with the trends in other indicators of rice demand, the MBS value for rice is highest among all staples (Table 2.7), implying that more spending will be allocated to rice when income levels increase. This demand is, however, sector specific, with the MBS for local rice being higher than for imported rice in rural areas, suggesting that additional income received by rural households will be spent more on local rice than on imported rice. Conversely, urban households spend higher shares of additional incomes on imported rice.

Table 2.7 Marginal budget shares and income elasticity of demand

Commodity	Urban		Rural		National	
	Marginal budget share (%)	Income elasticity	Marginal budget share (%)	Income elasticity	Marginal budget share (%)	Income elasticity
Rice	2.4	0.43	5.4	0.77	4.2	0.63
Rice—local	0.4	0.2	3	0.64	1.7	0.46
Rice—imported	2	0.54	2.4	1.04	2.4	0.87
Maize	0.7	0.64	1.9	0.71	1.4	0.64
Wheat	1.2	0.7	1.8	1.18	1.6	0.99
Sorghum/millet	0.1	0.07	0.7	0.13	0.3	0.07
Other grains	0.2	1.35	0	0.41	0	0.34
Cassava	0.7	0.21	2.2	0.47	1.4	0.33
Yam	2.1	0.47	3.4	0.64	2.9	0.57
Other roots	0.8	0.6	1.2	0.74	0.9	0.62
Pulses	1.2	0.41	2.2	0.57	1.7	0.48
Oils and fats	1.8	0.38	3.6	0.54	2.9	0.47
Fruits/vegetables	2.6	0.5	4	0.57	3.4	0.52
Milk	1.1	1.04	1.1	1.04	1.1	1.02
Poultry	2	2.27	2.1	1.92	1.9	1.85
Other meat	4.3	0.81	7.7	1.26	6.3	1.07
Fish	2.4	0.44	4.2	0.72	3.6	0.62
Other food	2.8	0.9	3.5	0.92	3.2	0.92
Dining out	20	1.57	14.2	1.52	16.9	1.62
Nonfood	53.6	1.36	40.7	1.54	46.3	1.52
Total	100		100		100	

Source: Authors' calculations from Nigeria's Living Standard Measurement Study–Integrated Survey on Agriculture (Nigeria, NBS; and World Bank 2011).

Finally, income elasticity is examined to determine how much demand for a commodity would change following a percent change in income. We estimated income elasticity econometrically from a semilog inverse function suggested by King and Byerlee (1978).[6] Results are also presented in Table 2.7, where the income elasticity of rice is shown to be 0.43 and 0.77 for urban and rural households, respectively. In this case, rice can be seen as a normal good, with higher elasticities observed in rural areas. Estimating income elasticities for local and imported rice individually, we find different patterns in rural areas, where the elasticity of imported rice is higher than 1, implying that rural households perceive imported rice as a luxury good and would demand more imported rice given higher incomes. However, income elasticity of local rice is still much higher in rural than in urban areas, which shows that demand for local rice would increase much more in rural than in urban areas given a higher income level.

In Table 2.8, we contrast these elasticities with those from other developing countries. Nationally, the income elasticity of demand for rice in Nigeria is around 0.63, which does not differ much from values found in other African countries (Table 2.8). Christensen et al. (1981) estimated the income elasticity of rice for various regions of Africa south of the Sahara. The reported income elasticity of demand for rice in this study for the West Africa region was about 0.65. The highest income elasticities were reported in the central and Sahel regions (0.93). In contrast, most Asian countries have low income elasticities of demand for rice, and the values are even negative in some countries, where rice has become an inferior good. The lowest value is observed in Japan and Taiwan, with values of -0.53 and -0.59, respectively, while Indonesia has the highest value, of 0.47.

[6] The authors found the semilog inverse function to be more flexible and to provide a better fit in their application across commodities consumed in Sierra Leone. It has since been widely used by others. See, for example, Diao, Fan, Kanyarukiga, & Yu (2010).

Table 2.8 Income elasticity of demand across countries/regions

Country/region	Income elasticity of rice demand
Africa	
Burkina Faso[a]	0.8
Sahel region[b]	0.93
Western region	0.65
Central region	0.93
Eastern region	0.58
Southern region	0.56
Asia[c]	
Taiwan, China	-0.59
Japan	-0.53
Singapore	-0.52
Malaysia	-0.35
Thailand	-0.33
China	0.29
Philippines	0.32
Indonesia	0.47
Burma	0.46

Sources: [a] Savadogo and Kazianga 1999; [b] Christensen et al. 1981; [c] Duff 1991.

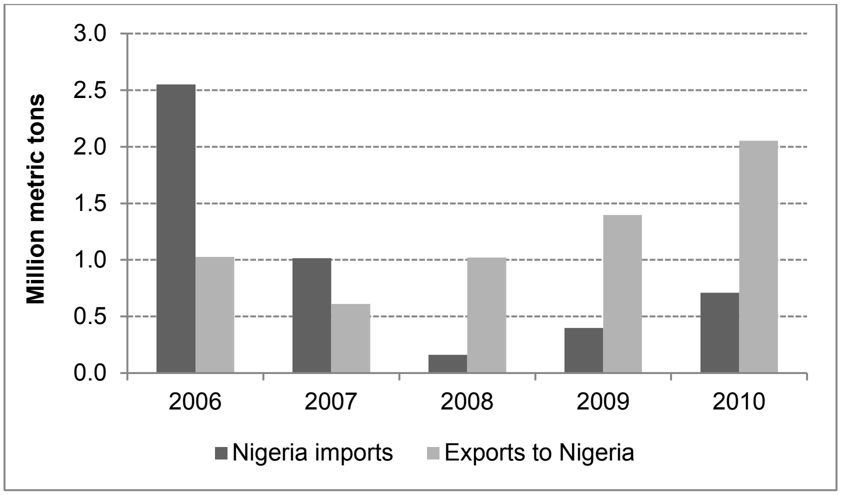
Overall, the income elasticity of demand for rice in Nigeria is still quite high, suggesting that demand for rice would grow fast as income level increases. This pattern is observed for both local and imported rice, and rural households show higher demand for rice compared with urban households when their incomes increase. Even though rural households would spend more from additional income on local rice than on imported rice in monetary terms, it appears that they still aspire to be able to afford imported rice and would probably switch consumption at some critical income level. Also, imported rice has higher income elasticities in both urban and rural areas, so it is preferred across the country.

There are indeed some challenges to taking full advantage of potential rice demand in the country. The high demand for local rice in rural areas presents an opportunity to deepen market shares in rural areas. Tougher challenges are observed in urban areas, where imported rice has taken over most of the market share. Since imported rice is demanded mainly due to attributes and quality preferences, improvements in the efficiency of the entire value chain and in product quality need to be pursued to improve the capacity of local rice to compete with imports. By persistently tackling these current and future challenges, Nigeria, it is hoped, will be able to take full advantage of its production potential in order to attain its goal of rice self-sufficiency and also improve the welfare of society.

Resulting Trends in Imports and Prices

While official figures paint a steady increase in imports, the actual figures are probably much higher. Using the latest data from the UN Comtrade database (UN 2012), we found rice imports in 2010 in Nigeria to be about 2.1 million tons (based on export data from the country's trade partners). Nigeria's official import figure from the same source is 711,000 tons, or about 35 percent of the world rice exports to Nigeria (Figure 2.2). Table A.1 in Appendix A breaks down in more detail information on rice imports and exports by country of origin to Nigeria between 2006 and 2010.

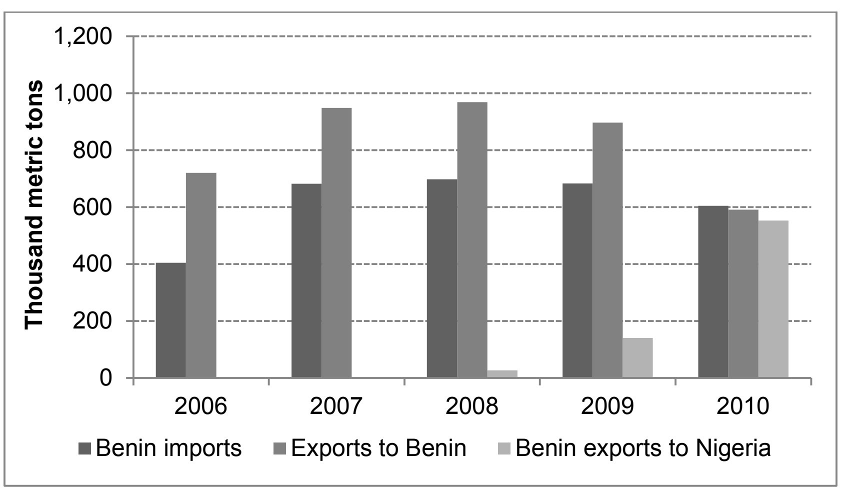
Figure 2.2 Rice imports by and reported exports to Nigeria



Source: Authors' calculations based on Comtrade data (UN 2012).

Aside from direct imports at Nigerian ports, cross-border trade flows with neighboring countries such as Benin are also a significant source of both recorded and unrecorded rice imports. Of its 600,000 tons of imported rice, Benin reported re-exporting virtually all of it to Nigeria in 2010 (Figure 2.3)—while local sources claim that around 8,000 bags of rice (at 50 kg/bag) are smuggled into the country every day through waterways between Nigeria and Benin (Oryza 2012). This implies that smuggling is potentially equivalent to about 7 percent of total imports to Nigeria (world export data plus smuggling).[7] There is evidently some significant underreporting of official exports through Lagos as well as substantial unrecorded cross-border trade of imports from the international market across the Benin border. This situation indicates that a policy of imposing high import tariffs alone may not be sufficient for deterring imports and driving up demand for domestically produced rice.[8]

Figure 2.3 Rice imports and exports by Benin, and reported exports to Benin



Source: Authors' calculations based on Comtrade data (UN 2012).

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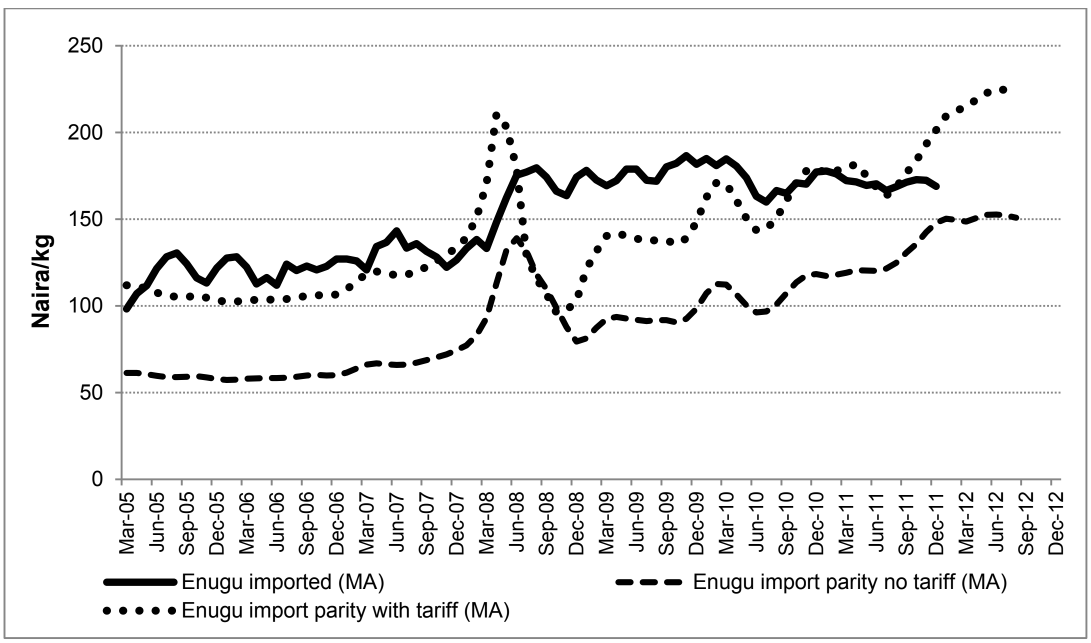
[7] The smuggled rice accounts for 8,000 bags x 50 kg/bag = 400 tons/day = 146,000 tons/year.

[8] More recently, at the time of this writing, a local media source noted fears of a growing smuggling enterprise in rice imports though Cameroon and Benin as import tariffs on rice increased (*Nigerian Tribune* 2013).

Production and consumption decisions depend on the prices faced by farmers and consumers. At the given levels of price incentives, demand for rice has exceeded supply in Nigeria. As already revealed, rice demand and supply are evidently not price elastic; that is, adjustment in prices through trade restrictions (such as tariffs) are unlikely to make Nigeria self-sufficient in rice production. As discussed in the previous section, rice demand is growing for a variety of reasons, including growth in incomes.

A simple analysis of price trends for imported rice brands under various import tariff regimes over time can also be useful in deciphering not only the effectiveness of the tariff but the extent to which local brands are substitutable with imported brands. Domestic prices of imported rice (at Enugu) broadly tracked import parity (100 percent import tariff) through December 2007. However, the sharp world price increase in 2008 was not completely passed on to the Nigerian market, and this despite the country's reducing the import tariff to zero by late April 2008. The rice import parity price dropped to below N 130 (Nigerian naira) per kg by June 2008 while domestic prices remained high. Imports thus appear to have been constrained during the period from mid-2008 through late 2009 (see Figure 2.4), a time when there were no official trade restrictions. The large gap between import parity prices and domestic prices suggests that there were substantial excess profits (rents) in this period. By early 2010, import parity prices had risen and were again approximately equal to the domestic price (at Enugu) through the end of 2011. Import tariffs averaged about 50 percent from mid-2009 through 2012, with potential tariff revenues (including any possible rents) estimated to have been about $800 million per year (or N 120 billion, at N 150/$1).[9]

Figure 2.4 Nigeria: Domestic and border prices of rice, 2005–2012



Source: Authors' calculations based on Nigerian National Bureau of Statistics data (Nigeria, NBS2012).

Notes: MA = monthly average.

Estimated monthly import tariff rates are as follows:

January 2005–April 2008: 100 percent (extending 2004 rate from Kym Anderson of the World Bank); May–October 2008: 0 percent (Ogutande, 2011); November 2008–April 2011: 64 percent (modal value of monthly average tariff collected, as calculated from Nigerian customs data); May–June 2011: Flat rate of $210/ton (30 percent x indicative price of $700/ton) = 45 percent of actual C&F (cost and freight) price; July–December 2011: Assume average effective tariff remains 45 percent; January–March 2012: Flat rate of $319.5/ton (50 percent x indicative price of $639/ton) = 54–57 percent of actual C&F price; April–August 2012: Flat rate of $349.5/ton (50 percent x indicative price of $639/ton) = 58–61 percent of actual C&F price.

[9] 2.0 million tons/year x $400/ton = $800 million/year = N 120 billion (@ N150/$1).

An analysis of the growth rates of domestic and imported rice prices over time also presents a telling picture of the extent to which domestic brands are substitutable for imported brands. Retail prices of imported rice in Enugu have declined by about 40 percent in real terms since their peak of nearly N 300/kg in mid-2008 (in 2012 nairas). The long-term (2001–11) annual growth rate in real prices of different varieties of rice is negative (Table 2.9). However, the long-term decline in prices is slowest for imported rice, at 0.05 percent. The long-term real prices of domestic rice (premium long-grain and standard) declined faster than imported rice prices, at 0.79 and 1.44 percent, respectively. Considering that domestic production of rice has been going up (as discussed in the previous section), this trend in prices indicates a greater consumer preference for imported rice than domestic rice and supports the same conclusion reached by the demand analysis in the previous section.

Table 2.9 Summary of urban rice prices in Enugu

Category/Year	Domestic premium, long-grain (2012 nairas/kg)	Imported premium (2012 nairas/kg)	Domestic standard, broken (2012 nairas/kg)
Average real prices			
2001–05	182.2	219.6	166.2
2005–10	179.1	226.9	162.7
2011	152.5	184.4	135.7
Ratio to long-grain			
2001–05	1.00	1.21	0.91
2005–10	1.00	1.27	0.91
2011	1.00	1.21	0.89
Annual growth rate (percent)			
2001–05	3.55	4.60	-0.24
2005–10	-1.49	-0.08	-2.94
2001–11	-0.79	-0.05	-1.44

Source: Authors' calculations based on Nigerian National Bureau of Statistics data (Nigeria, NBS 2012).
Note: Annual growth rates are calculated using logarithmic regressions of monthly price data. All prices are for urban markets in Enugu.

Summary Conclusion

The demand and preference for premium-quality rice in Nigeria is likely to continue growing with population and income in both urban and rural areas. Without a sufficiently rapid growth in rice production and in competitiveness with quality imported brands, Nigeria will continue to have to rely on imports to fill the gap. This underlines the fundamental goal of the government's ATA. But as we have shown here, while the introduction of high import tariffs is intended to support such a goal, it comes at a cost by encouraging smuggling, underreporting, and possible excessive rents. On the other hand, combining it with other investments to increase competitiveness through augmenting value chains, increasing technology adoption, and improving farming and processing techniques as the government is already doing has the potential to dramatically increase output. The extent to which such an increase can be sufficient to displace imports altogether is remains big question nevertheless. These concepts are explored in greater detail in the following sections.

3. STRUCTURE AND PERFORMANCE OF THE RICE VALUE CHAIN[10]

Rice production in Nigeria and West Africa in general dates back 2,000 to 3,000 years ago, mostly in the flood plains of the Niger river and involving one of only two species of cultivated rice in the world, *Oryza glaberrima,* or African rice.[11] The introduction of the second species, *Oryza sativa,* or Asian rice, would occur after the arrival of the Portuguese in the 17th century (Linares 2002). However, it is only during the last few decades that Asian varieties, or those crossbred with African varieties (such as the *new rice for Africa*, or NERICA rice), began to take center stage as an important food security commodity as demand outstripped production, as discussed in the previous section in the case of Nigeria. In this section, we seek to review the current rice production system in Nigeria—its structure, performance, and underlying constraints—along the entire value chain, from on-farm paddy production to its conversion into milled rice before entering retail markets.

Paddy Rice Production Systems and Performance

The dominant rice production systems in Nigeria can be described as comprising lowland, upland, and irrigated rice. Among these, the lowland rice system produces about 43 percent of total domestic production (Table 3.1). This is a system mostly found in river valleys and shallow swampy areas in several states, and especially in the *fadama* farming system areas in Niger and Kaduna states.[12] Another 29 percent is from irrigated rice, with the rest coming from upland systems. Naturally, yields are highest for the irrigated system (more than 3 tons/ha on average), followed by the lowland systems (between 2 and almost 4 tons/ha on average). The majority of the rice grown across all three systems is produced by small-scale farmers on plots of 1 to 2 ha . The majority of rice producers are found in the central Guinea Savannah (semihumid) and northern Sudan Savannah (semiarid) zones of Nigeria. However, rice is also produced by small-scale farmers on irrigated land or river banks in the far north and Sahel region and as an intercropped system in the more humid south regions (or tropical rain forest region).

In the lowland rice system, which makes up more than half of the total area under rice, there are wide variations in the intensity of production and use of modern inputs and water control practices. Land preparation can vary from traditional practices of cultivation to the use of herbicides and mechanized tillers. Water control methods, such as bunding, are not common everywhere. Rice is either directly seeded or transplanted. In almost all cases, it remains a single-year crop except in irrigated areas. Average yield performance of this system is about 2.2 tons/ha—higher than upland but lower than irrigated systems.

Table 3.1 Dominant rice production systems in Nigeria

Production system	Average share of national area (%)	Average share of national production (%)	Average yield range per year (metric tons / ha)
Lowland (rainfed)[a]	52	43	2.0–3.0
Irrigated[b]	16	29	3.0–4.0
Upland (rainfed)	30	27	1.0–2.0
Mangrove (deep water)	2	1	-

Sources: Estimates adapted from Table 1 in Ezedinma 2005 and Table 1 in Erenstein et al. 2004.

Note: [a] Yields can be much higher in some areas, with averages as high as3.9MT/ha according to the more recent Nigeria National Rice Survey, 2009.

[b] This category may include some rainfed lowland production with partial water control. The rice area under a fully developed irrigation system should be much smaller.

[10] This section was authored by Michael Johnson and Akeem Ajibola

[11] For a useful account of the history of rice in West Africa, see Linares (2002).

[12] *Fadama* is a Hausa name in Nigeria for irrigable land in low-lying plains of shallow aquifers found along major river systems.

In the upland rice systems, intercropping sometimes occurs—especially with maize, cassava, yams, and vegetables (Longtau 2003b). Rice is seeded directly or broadcast on level and sloped hillsides. Land preparation is typically done by hand hoes, as it is for all other crops. Yields are highly susceptible to rainfall patterns each year, performing better in the south on average due to higher rainfall. However, with the growing use of NERICA rice varieties, yields of upland rice in the central and northern are likely to be even higher.[13] As a result, much of upland rice is grown in the south, which also explains the general practice of intercropping common in the humid forest zones in this region. Among traditional varieties grown, *ofada* rice is the most popular.

Irrigated rice systems are scattered across Nigeria and linked to water resources from major rivers, dams, and other water bodies or lakes. Many still depend on the few large irrigation systems built in the 1970s and 1980s that have remained operational—although not at full capacity (Longtau 2003a). Many such systems have collapsed over time due to lack of proper maintenance. Among those operating, the highest average yields are about 3.5 tons/ha. On farms with adequate access to water year-round, two crops can be produced each year.

The rice ecologies and production systems cut across political state boundaries, with higher-producing areas of lowland rice dominated by the river valleys of Niger, Benue, Ebonyi, and Kaduna states, for example (Longtau 2003a). Upland systems among states with higher production levels include Ekiti in the southwest and Gombe and Borno states in the north. Irrigated rice is mostly found in the north, in Borno, Jigawa, Kano, and Katsina states, with some lowland irrigation systems also in Niger and Enugu states.

Among all states, more than 40 percent of paddy rice produced in Nigeria comes from the three states of Niger, Kaduna, and Kano (Table 3.2). With a significant share of lowland rice ecologies, Kaduna and Niger alone contribute 30 percent. All three states reportedly have relatively high yield performance and produce more than 300,000 tons per year on average. Those states that produce between 200,000 and 299,000 tons—Benue, Ebonyi, Borno, Taraba, and Adamawa states—contribute another 34 percent to national output. Altogether, these eight leading rice-producing states (those with 200,000 or more tons per year) account for about three-quarters of national rice production. Other states that produce at least 50,000 tons but less than 200,000 tons include Plateau, Kogi, Nasarawa, Gombe, Yobe, Kwara, Sokoto, Kebbi, and Jigawa.

Constraints and Opportunities

Among all rice ecologies, weed control is considered one of the most important yield-reducing factors due to its high demand on labor inputs and soil nutrients, which contributes to lower levels of land and labor productivity (Defoer et al. 2004). The problem is exacerbated by reduced fallowing, which is leading to decreased soil fertility and land degradation problems over time. Second to the challenges of weed control and soil fertility, problems of drought, disease (such as blast), and pests are also common. The most common rice plant diseases found in Nigeria include blast, which can be severe in drought-prone rainfed systems, and rice yellow mottle virus and leaf scald in irrigated and more humid areas (Longtau 2003a). Common pests include birds and rodents. Many of these constraints have been brought under control in areas where the adoption and diffusion of improved varieties has been widespread.

[13] Based on the Nigeria National Rice Survey (2009) which reported adoption rates of about 25 percent for improved NERICA varieties.

Table 3.2 Paddy rice area, production, and yield in Nigeria, three-year averages, 2007–2011

Range	> 300,000 MT	200,000–299,000 MT	50,000–199,000 MT	< 50,000 MT	Total
States	Kaduna, Niger, and Kano	Benue, Ebonyi, Borno, Taraba, and Adamawa	Plateau, Kogi, Nasarawa, Gombe, Yobe, Kwara, Sokoto, Kebbi, and Jigawa	All other states	National
Share of national production (%)					
2007–2009	39.9	33.8	18.8	7.5	100
2009–2011	40.2	33.7	18.7	7.4	100
Area ('000 ha)					
2007–2009	561	616	301	161	1,638
2009–2011	696	805	346	206	2,054
Production ('000 MT)					
2007–2009	1,342	1,139	635	251	3,367
2009–2011	1,516	1,271	707	281	3,775
Yield (MT/ha)					
2007–2009	2.4	1.8	2.1	1.6	2.1
2009–2011	2.2	1.6	2.0	1.4	1.8

Sources: Nigeria, NBS and FMARD 2011; Nigeria, NAERLS 2009.
Note: MT = metric tons.

In the lowland rice ecology, water control has also been shown to be a critical constraint to intensification and maximizing yield potential. Land preparation methods become critical in this regard, including the use of herbicides and mechanized tillers. Given the ecology's importance in supplying the bulk of rice in Nigeria, there is great potential to improve its performance through improved water control methods and use of modern inputs and technologies. Additionally, the lowland systems often integrate well with aquaculture production, given sufficient water levels during the early stages of production.

Despite the low levels of rice intensification, the use of improved rice varieties has a long history in Nigeria. In fact, among West African countries, Nigeria has consistently led in the development and diffusion of improved seed for all three major rice ecologies. The National Cereals Research Institute has conducted varietal improvement research in Nigeria for more than half a century. According to Dalton and Guei (2003a), the first official release of an improved rice variety in Nigeria occurred in 1954 for the rainfed lowland system, and since then more than 50 improved varieties have been released. The most popular seeds adopted by farmers have typically exhibited traits of early maturing and high yields (Longtau 2003a). Diffusion rates of modern improved varieties are highest in irrigated lowland areas and moderate in upland areas, but still low in rainfed lowland ecologies (Dalton and Guei 2003b).

Unfortunately, maximum yields are rarely realized due to limited access to and inefficient use of complementary technologies such as fertilizer, land cultivation techniques, weeding, and water control. Part of the problem has been the high cost of inputs such as fertilizer, chemicals (herbicides and insecticides), and mechanized implements (tractors and tillers). The use of tractors has been limited to large-scale irrigated areas and, mostly on a fee-for-service basis, areas where the land has been parceled out among many small-scale farmers. For the majority of farmers, owning a tractor is next to impossible given its high up-front capital cost and high operating and maintenance costs.

Structure and Conduct of the Rice Postharvest Sector

Once the paddy has been harvested, it has to undergo various processing tasks to be converted into milled white rice before reaching consumer markets. At harvest, paddy or rough rice contains an outer layer (or husk) and a bran covering the grain seed. The removal of these outer layers constitutes the milling process. When only the husk is removed the result is brown rice, and when further milling occurs to remove the bran this converts it into white rice. A process of parboiling the paddy rice may also occur before the milling process begins as is common in Nigeria. The entire parboiling process involves washing, boiling, soaking, and steaming the paddy before drying it in the sun, which can take up to three days (Lançon et al. 2003b). The parboiling task is necessary because most Nigerians prefer it for its taste and texture in preparing local rice dishes (Bamidele, Abayomi, and Esther 2010). It is also for this reason that most Nigerian consumers prefer the Thai parboiled rice among imported brands (Ogunbiyi 2011). Parboiled rice also offers other advantages: a higher recovery rate during milling and higher preservation of its nutritious properties after milling (Tinsley 2011). Milling is typically done using a mechanized dehuller (or dehusker). While traditional hand pounding methods are still practiced, this is becoming less common and then mostly for home consumption (Akpokodje, Lancon and Erenstein (2001). After milling, a cleaning stage involves separating small stones from the rice, either by hand or with use of a mechanized de-stoner. Further processing may also be carried out, especially by modern mills, such as polishing (buffing the white rice with glucose or talc powder) and sifting and grading to separate any remaining small impurities and broken grains from the head rice. For the rice destined for market, a final process involves weighing and bagging the milled rice for the wholesale or retail market.

In Nigeria, the various processes described above involve many actors with varying degrees of skill and access to technologies, especially since the bulk of postharvest handling and processing is still very much a cottage industry made up of small-scale operators.[14] Figure 3.1 describes the various channels along the entire value chain by which rice is produced, milled, and marketed in Nigeria. The small- and medium-scale milling channel handles up to 80 percent of the total rice in domestic markets.[15] Most of the operators along this channel mill rice paddy from smallholder farmers and traders for a fee, either for own consumption or for rural markets. Based on the most recent available data, the share of rice milled for own consumption is about 14 percent while the rest enters the market, 63 percent going into rural and 22 percent into urban markets (Nigeria, NBS; and World Bank 2011). The economic activities along this chain involve many smallholder paddy farmers, small-to medium-scale millers, middle traders, and wholesalers and retailers. It is a highly disaggregated and fragmented channel—with rice changing hands several times at points of sale from farmgate to end market. As a result, there is naturally a wide variation in the quality of the final product, which inadvertently reaches consumers with unfavorable properties of discoloration and the presence of foreign matter (especially stones).

Most small- and medium-scale mill operators are located centrally within a cluster in a village or small town near paddy production areas. Consequently, areas with higher volumes of production usually have larger clusters of mills with higher operational capacities (medium-scale mills) and are more organized in procuring, milling, and selling of the final product, whether through the market or to middle traders (Lançon et al. 2003a). Some well-known examples are the clusters found in Lafia, Otukpo, and Abakaliki, with 100 or more millers. Capacity utilization is usually highest during the peak months after harvest, between October and December each year. For other times of the year, paddy is procured from further afield.

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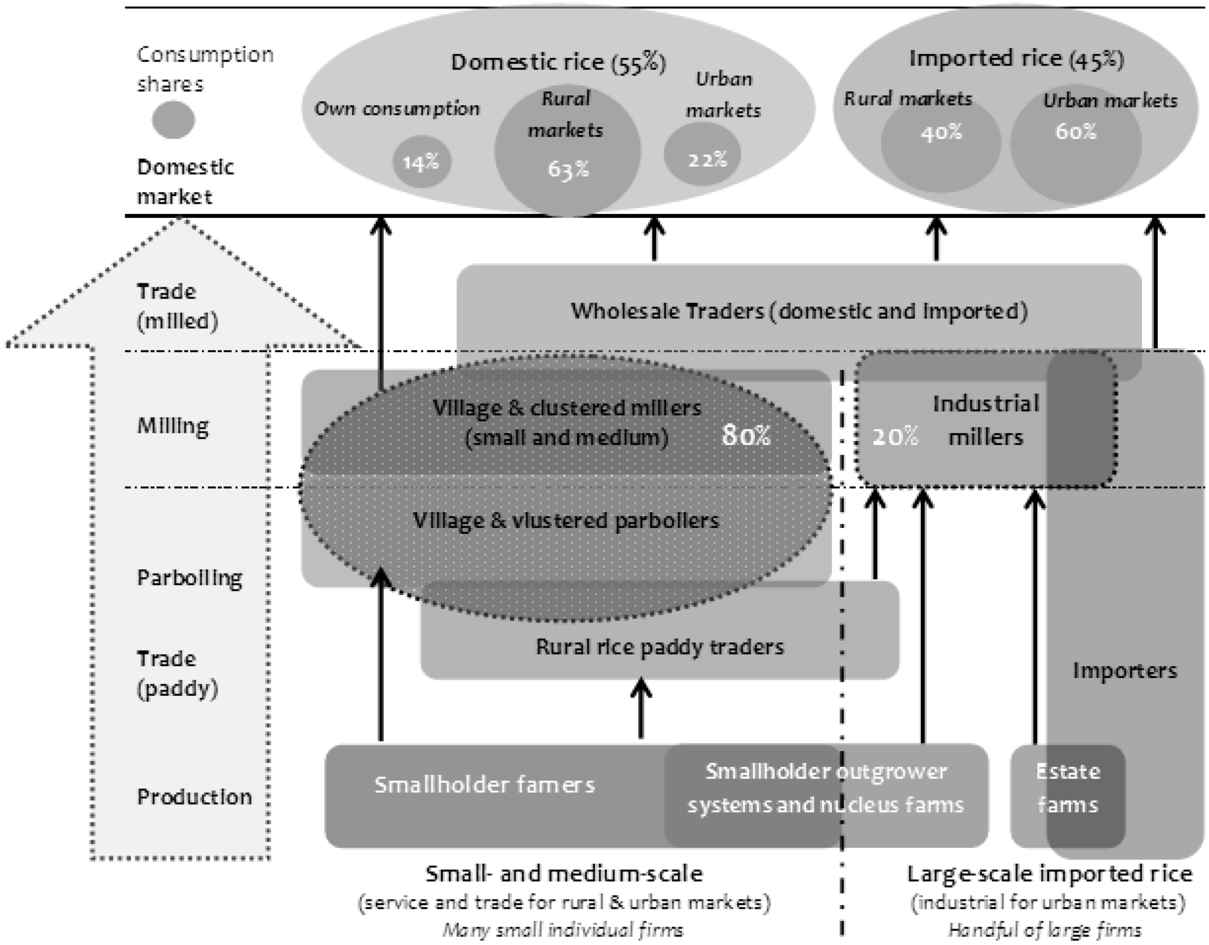
[14] Table A.2 in Appendix A reviews in more detail the various actors, their roles and functions, and key constraints within each major marketing channel.

[15] Borrowing from the study of Lançon et al. (2003b), we distinguish small- to medium-scale as having a milling capacity of less than 500 kg per hour. Lançon et al. (2003b) define small-scale as 50 to 149 kg per hour and medium-scale from 150 to 500 kg per hour.

Figure 3.1 Rice value chain in Nigeria



Source: Authors. Data on consumption shares are from *Nigeria's Living Standard Measurement Study–Integrated Survey on Agriculture* (Nigeria, NBS; and World Bank 2011). The schema has been adapted from Figure 3 in DAI 2009.

Middlemen traders play the critical role of bringing paddy from farmers to rice millers and milled rice to wholesalers and retail markets. Only a few trade in both paddy and milled rice, using the services of small- and medium-scale millers for a fee to mill the paddy they purchase from farmers before reselling it. Others are millers themselves, usually medium-scale operators or smaller operators in the large clusters, who buy their own paddy from farmers or paddy traders to process into rice and sell on the market. Though few in number, these two types of traders serve an important intermediate role in the bulking process of paddy, enabling them to be more selective about the type of paddy they buy, mill, and resell to the market, and in the process, to help ensure homogeneity in the final product (Lançon et al. 2003b). The rest and majority of middlemen traders serve either as paddy or milled rice traders and invest very little to upgrade the product itself (DAI 2009; Lançon et al. 2003b).

Despite differences in milling capacities between small- and medium-scale operators as defined, the two easily compete and overlap. The main difference is that medium-scale operators typically handle larger volumes, and among these are some who serve the dual role of miller and trader, wherein they buy their own paddy to mill and sell to traders downstream rather than simply milling for a fee. Although not common everywhere, such miller–traders may provide farmers with credit for inputs and even store their own paddy. However, when they do store paddy, at least according to the findings of Lançon et al. (2003b), this is mostly to help smooth their milling activities during the peak season rather than to hedge against future expected prices. In their capacity as miller–traders, as noted earlier, they do have the advantage of being able to be more selective in the paddy variety they wish to mill, even handling the parboiling task itself before milling, and in the process ensuring a better-quality product.

For the bulk of domestic rice, the reality is that milling comes from the segment of smaller millers who simply provide the service for a fee. Many of these have varied skills and degrees of access to technologies, services, and information along the entire supply chain, and care little about upgrading to better paddy varieties and processing technologies. Little vertical market integration is present in this sector, as evident from the surveys of Lançon et al. (2003a) and the authors' own field visits in Niger and Benue states, implying a weak link downstream between millers and retail markets. This is because the millers rarely deal directly with retail markets in their capacity of providing milling services or selling to traders on site and on a demand basis. Consequently, there are significant inconsistencies between rice variety names and milled rice brands, which make it virtually impossible to link production more directly with consumer preferences. It is therefore not surprising that the quality of the final product in market outlets varies substantially and the product is considered inferior to imported brands that can be relied on for consistent quality, taste, and texture.

The branding of a higher-quality grade of rice can occur more consistently when there is an established vertical link in the value chain, from a unique paddy variety to the final processed product in the marketplace, a condition that is typical among larger industrial-type milling sectors (for example, the export industries in Asia). However, the reach of this sector in Nigeria is limited to a handful of firms that mostly produce to meet demand in high-end urban markets while simultaneously importing rice for the same purpose. This is, after all, a premium product that is not easily substitutable with the more standard and lower-quality rice produced in higher volumes in Nigeria. Referring to Figure 3.1, this segment of the Nigerian rice market is represented by the two channels involving large-scale millers and imported rice.

There are only a handful of company brands that have existed in Nigeria over the years among the large and industrial-scale millers. These have included Olam, Veetee, Stallion, Dana Foods, Isyaku Rabiu Group, and Ebony Agro (Lodestar International 2010). For these firms, as elsewhere in West Africa, the dual role of serving as an importer and a larger miller helps guard against uncertainties related to global price volatility and domestic policies (Demont and Rizzotto 2012). As a result, the sector has not always been consistent, producing very little or nothing at all in some years whenever it was less profitable to handle domestically produced rice relative to imports.[16] At the end of 2008, for example, one source identified only two large industrial mills in operation that year: Olam and Veetee (DAI 2009). Although large-scale operators can potentially handle a larger share of milled rice in the country (up to 45 percent, according to Lançon et al. 2003b), they are typically forced to operate well below capacity due to inadequate supplies of paddy rice from year to year; this explains their limited scope to date. In 2002, for example, the survey by Lançon et al.(2003b) estimated that only 32 percent of total capacity was being utilized, compared with more than half for small- and medium-scale operators. Aside from the risks of underutilizing existing capacity, the high up-front capital investment required to set up a large industrial mill makes it prohibitive for most investors to consider.

[16] Quite a few of the large operators import parboiled brown rice directly from Asia to then mill into rice locally. This can ensure a steady supply for the millers, subject to global price trends and any import barriers.

Performance of the Rice Value Chain

To measure the average performance of the rice value chain in Nigeria, information was gathered on best estimates of the cost and price structure associated with the different activities along the chain in order to determine their individual margins and eventual price competitiveness with imports. Combining data from the literature and field trips to a few of the large rice-producing states in Nigeria (Niger, Kano, and Benue), we compared these costs with those reported for a couple of Asian countries—Thailand and Bangladesh.[17] The estimates for all three countries are mostly representative of costs associated with smallholder paddy producers, small- to medium-scale processors (including millers), and domestic market prices. Thailand offers a useful benchmark because the bulk of Nigeria's imports come from this country. Additionally, Thailand is considered to have one of the more efficient rice value chains in the developing world, even though average milling costs could be even lower if existing large rice mills could operate at full capacity every year (Titapiwatanakun 2012). By comparing Thailand's costs and marketing margins, we can distinguish parts of the value chain in Nigeria that are inefficient or operating at a comparative disadvantage. Comparison with Bangladesh, on the other hand, is intended to offer an alternative benchmark with a net importer (like Nigeria) among major rice-producing countries in Asia.

Figure 3.2 presents average differences in efficiencies across the entire value chain in Nigeria and Thailand. At the outset, the data reveal that rice production costs per unit of output in Nigeria are almost double those in Thailand on average ($478/ton versus $254/ton in their milled rice weight equivalent). Based on data from a number of studies and international database sources, an FOB price at the port of Bangkok was computed to be about $0.60/kg ($604/ton) for Thailand's "parboiled rice 100%" in 2009—the year for which sufficient information on the Thai rice value chain was readily available (see Maneechansook 2011). Because this FOB price level corresponds well with current levels in 2012, we compared this with data collected in the field in Nigeria and corroborated by other estimates (for example, Chemonics 2009; DAI 2009). Adding freight and port charges to the Bangkok FOB price, the cost, insurance, and freight (CIF) at Lagos turns out to be $0.66/kg, which is lower than the average wholesale price of $0.83/kg for domestically produced rice.

Evidently, under zero tariffs rice produced in Nigeria cannot compete with imports on price, let alone quality. Only if we include an import tariff of about 30 percent, and this time considering domestic transportation and marketing costs (say about 30 percent of CIF price), does the final import parity price at retail of $1.12/kg (N 177/kg) rise above an average retail price of $0.92/kg (N 146/kg) for domestic rice.[18] For consumers, such a price differential makes sense, considering the inferior quality of domestic rice (that is, a 22 percent premium for quality alone).[19] Similar conclusions were drawn in the study by Lançon et al. (2003b), which estimated quality premiums of up to 25 percent. Such a differential in premium can be considered as a potential income gain from increasing the competiveness of local rice.

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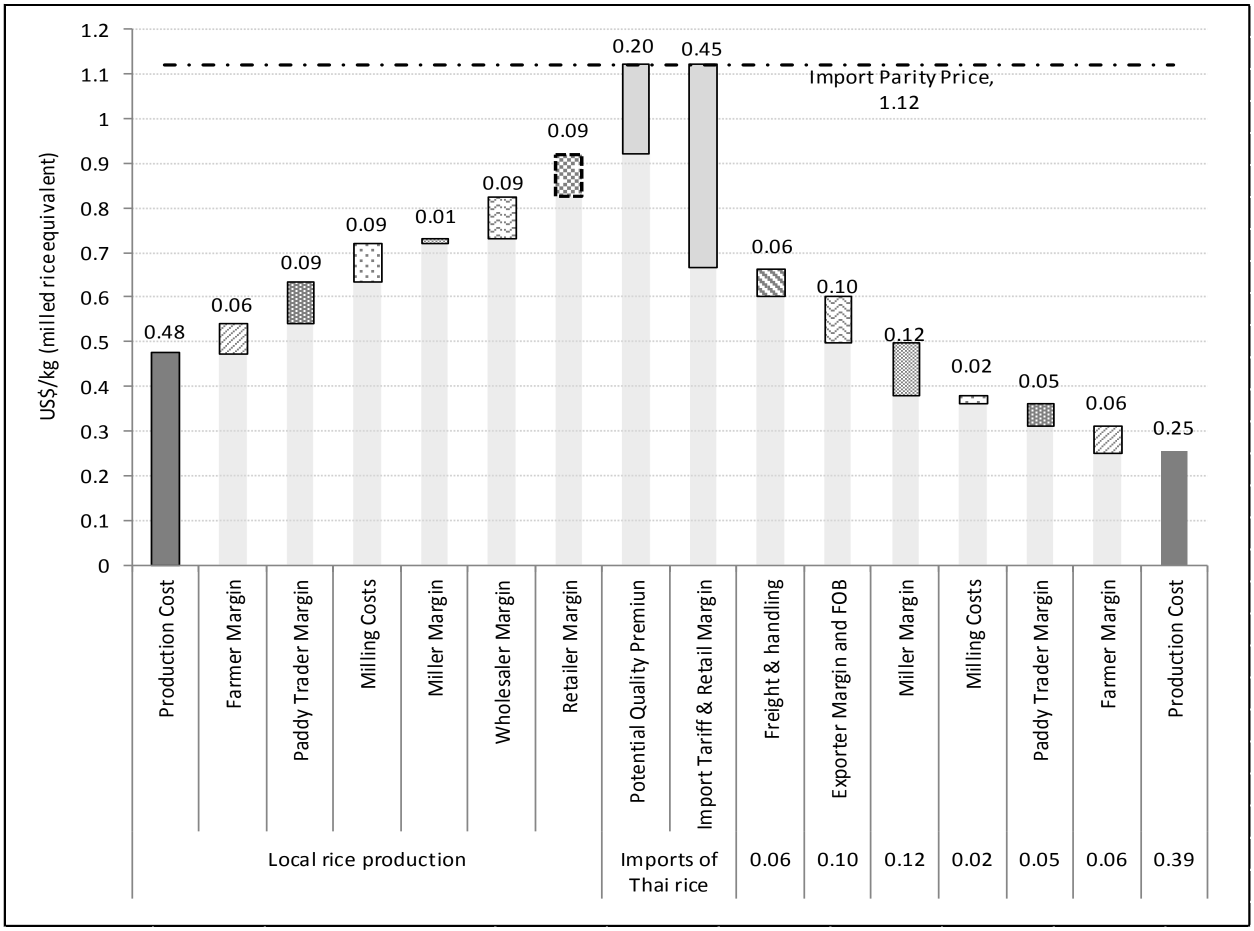
[17] The Nigerian data are mostly based on cost estimates in one of the major rice-producing states, Niger. Some adjustments were made based on secondary data sources, cited under each graph or table. Data for Thailand and Bangladesh are secondary, with the source cited. These are meant only to be indicative of average performance.

[18] Retail and wholesale prices of domestic rice are based on monthly averages in 2011 collected by FEWSNET (the Famine Early Warning Systems Network) in one of the major rice marketing centers in Nigeria, in Bodija (Ibadan). The prices for imported rice in 2012 are easily around N 200/kg. So these figures are quite conservative but compare well with other prices used elsewhere in the study (for example, from markets in Enugu).

[19]An exception is *ofada* rice, which is considered to have high-quality premium characteristics—but has only a small niche market relative to total rice demand.

Figure 3.2 Comparison of rice value chains between Nigeria and Thailand, 2009



Sources: For Nigeria, based on authors' own field visits in Niger State and estimates by Chemonics 2009; for Thailand, based on Maneechansook 2011 and FOB data from the Thai Rice Exporters Association for "parboiled rice 100%" (www.thairiceexporters.or.th).

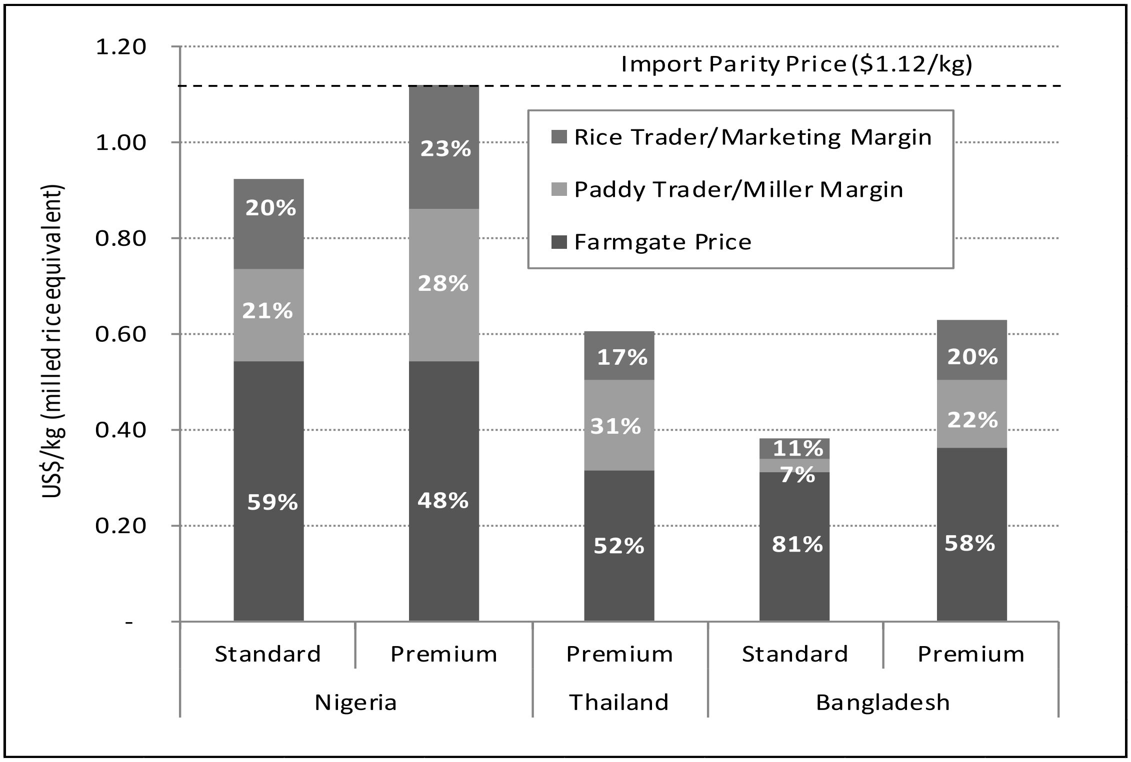
Note: Processing costs for Nigeria here are for small- to medium-scale processors. The "import and retail margin" component of Thai rice assumes an import tariff of 30 percent and a domestic transport and marketing cost of about 30 percent of the price with cost, insurance, and freight. All unit costs are in milled rice weight equivalents.

Ignoring costs and comparing the price structure along the wholesale (or exporter) value chain between Nigeria, Thailand, and Bangladesh can help highlight the principal activities in the chain that capture the highest margins. This time, for Nigeria we distinguish between processing standard and higher-quality premium rice. The standard brand represents current quality levels while the premium brand is considered to be of a high enough quality to be substitutable with imports. Data for the standard brand are the same as in Figure 3.2. Data for the premium brand are taken from Oguntade (2011), who surveyed the costs and profit margins of a sample of medium- and larger-scale operators in the Abakaliki industrial cluster of Ebonyi State in 2009. The millers had an average milling capacity of about 600 kg per hour. As shown in Figure 3.3, farmgate and retail prices are significantly higher in Nigeria than in the other two countries for both the standard and premium brands.[20] Naturally, the milling and trader margins for the domestically produced premium rice are much higher as they use more advanced milling technologies and undertake further processing, such as de-stoning, polishing, and packaging. Paddy trader costs also turn out to be higher because the millers in the area are often forced to procure paddy over long

[20] All values in Figures 3.2 and 3.3 were converted to constant real 2009 US dollars and milled rice weight equivalent to allow for a more accurate comparison.

distances. Most of the millers were found to be operating well below capacity, which increased their per-unit operating costs (Oguntade 2011). While they are potentially able to compete with imports on quality, they cannot do so on price unless import tariffs are sufficiently high. In this case, a 30 percent levy resulted in a comparable import parity price of $1.12/kg, as illustrated in Figure 3.3.

Figure 3.3 Price structures of the rice value chain in selected countries



Sources: For Nigeria, authors' calculations based on field visits in Niger State, estimates by Chemonics 2009, and for premium rice, Oguntade 2011; for Thailand, based on Maneechansook 2011 and FOB data from the Thai Rice Exporters Association for "parboiled rice 100%" (www.thairiceexporters.or.th); for Bangladesh, based on Minten, Murshid, and Reardon 2013, referring to fine-quality rice grain.

Notes: Prices are in 2009 US dollars and have been converted to their milled rice weight equivalents. *Standard* for Nigeria refers to the bulk of local rice sold in domestic markets in Nigeria, typically produced by the small- to medium-scale sector. Nigerian *premium* refers to local rice that is more substitutable with imports and produced by large industrial mills. Information on the latter (based on data from Oguntade 2011) is from surveys in Benue State of medium- to large-scale millers in the Abakaliki industrial cluster with an average milling capacity of 60o kg per hour. Most millers were operating at well below capacity (about half). For Bangladesh, *standard* refers to the more common "coarse" rice brand while *premium* refers to the "fine" brand targeted to higher-end urban markets.

The price structure in Asia contrasts sharply with Nigeria's. For both Thailand and Bangladesh, the farmgate price captures a larger share of the final retail price for premium rice (about 50 to 60 percent). In Thailand, millers and exporters also capture a significant portion, about 31 percent and 17 percent (respectively), corroborated by other studies, for example, those of Maneechansook (2011) and Agrifood Consulting International (2005). In Bangladesh, about 22 percent of the final retail price represents the combined costs and profits of paddy traders and millers, with the rest (20 percent) going to retail traders (Minten, Murshid, and Reardon 2013). Yet millers in these countries are still able to experience significant profit margins, up to 32 percent in Thailand, for example (Table 3.3). For Nigeria, millers' margins vary a lot, but usually they are very low, as in the example of Table 3.3. Oguntade (2011) reported that the profit margin for larger, medium-scale millers is not very high either, only about 7 percent.

Table 3.3 Comparison of production costs, yields, and profit margins

Measurement	Nigeria	Thailand	Bangladesh
		Input costs	
Production costs ($/MT)	478	254	313
Milling costs ($/MT)	85	17	-
		Paddy yield and returns	
Paddy yield (MT/ha)	1.9	2.9	4.2
Farmer return ($/ha)	123	177	207
		Profit margins	
Farmer profit margin (%)	13.7	24.2	15.8
Miller profit margin (%)	1.7	32.0	-

Sources: Authors' calculations based on the following: for Nigeria, field visits in Niger State, estimates by Chemonics 2009, and Oguntade 2011; for Thailand, Maneechansook 2011 and FOB data from the Thai Rice Exporters Association; for Bangladesh, Minten, Murshid, and Reardon 2013; for dollar value of agriculture per worker, World Bank Development Indicators (2012); for yields, FAOSTAT (FAO 2012). No comparable data existed for Bangladesh on milling costs and profit margins.

Note: MT = metric tons. Prices are in 2009 US dollars. Input costs are in milled rice weight equivalents.

Evidently, a key area for improving the competitiveness of domestic rice is going to be not only ensuring better product quality but lowering processing, trader, and marketing costs to increase incentives to upgrade.

At the farm level, Nigerian smallholder paddy farmers seem to share the same profit margins as their Asian counterparts. Using national averages for yields, production costs, and prices, Table 3.3 shows Nigerian farm-level profits as reasonably close to those of both Thailand and Bangladesh. Thailand's higher margins may actually be partially due to a government support program. In absolute terms, however, Nigerian farmers earn lower margins per ha due mostly to their lower yield, about $123 per year compared with $177 and $207 for Thailand and Bangladesh, respectively. With regard to production costs, Thailand enjoys much lower costs per ton for both paddy production and milling relative to Nigeria, a sign of higher efficiencies in the technology and inputs being used.

The poor performance of the entire Nigerian rice value chain relative to that of Asian countries leaves a lot of room for improvement. Per-unit costs for paddy production, milling, trading, and marketing are much higher than those in Asia. Post harvesting costs are especially high for the larger mills (the premium brand in Figure 3.3) because they often have to operate below capacity and seek paddy from further afield. According to Figure 3.3, the larger-scale millers (premium brand) experience up to 50 percent higher miller, trader and marketing costs than those of smaller millers (standard brand).

Constraints and Opportunities

In analyzing and comparing the two distinctive value chain sectors for domestic rice in Nigeria, the small- to medium- and the large-scale milling sectors, a number of constraints and opportunities associated with each emerge, as summarized in Table 3.4. To begin with, because the large industrial sector enjoys the advantage of having a higher milling capacity and modern technologies for supplying premium-grade rice, it has greater potential to compete with imports. But it is less economically efficient, considering that it is often forced to operate well below maximum capacity due to insufficient access to quality paddy. Because much of the paddy is produced by smallholder farmers, this is a tough challenge. The smallholder rice farming sector in Nigeria varies widely with regard to paddy yield and varieties of seeds grown, in addition to the type of production system and inputs used as well as distance to major processing centers and markets. All of this introduces a logistical nightmare in procuring the right quality and quantity of paddy in a timely and well-coordinated fashion. In the past, large millers have had to resort to traveling great distances or establishing outgrower systems to procure sufficient quantities of quality paddy. However, even these tactics did not always guarantee a sufficient supply, and in the end it would prove too costly to stay in business due to the higher per-unit operating costs of not utilizing the full capacity of the mills and due to the added search and administrative costs in trying to secure paddy. To circumvent these problems, some millers have chosen to start growing their own paddy on large-scale irrigated lands (Box 3.1 on the Olam example). Alternatively, the government is also proposing to set up a number of smallholder nucleus farms that will cultivate paddy on large irrigated lands in close proximity to the large modern mills (Adesina 2012).

As still very much a cottage industry, the more dominant small- to medium-scale milling sector has remained quite vibrant in its ability to procure, process, and market the bulk of the paddy being produced by thousands of smallholder farmers scattered all over Nigeria. This is also a sector that is more likely to positively contribute to the transformation of the rural economy, given its scope for generating incomes and employment and ensuring affordable food prices for the majority of consumers. The sector not only employs many processors and traders, including women, but also provides a cheaper alternative for millions of poor rice consumers in the country, as a number of research studies have shown (see, for example, Akighir, Ngutsav, and Asom 2007; Basorun 2008; Agwu and Ibeabuchi 2011; and Ayoola et al. 2011).

Table 3.4 Disadvantages and advantages of small- to medium-scale and large-scale millers

	Small- to medium-scale	Large-scale industrial
Disadvantages	• Varying quality and knowhow—some with reasonable quality • No grades and standards, difficult to access credit, poor record keeping • Little investment to improve or upgrade milling machinery, marketing, and branding • Output expands only with an increase in the number of processors • Many disassociated actors along the value chain increases complexity of improving product quality • Not easily substitutable with imports	• High up-front investment costs, including operating costs, which can be prohibitive without credit subsidy • Requires sufficient access to quality paddy— for example, via vertical integration with paddy producers for consistent variety (either via outgrower systems or large-scale producers, including own) • Potentially displaces more vibrant small- to medium-scale milling sector • Employs less labor due to being highly capital intensive—and thus has less impact on transformation of rural economy
Advantages	• Cottage industry and highly competitive • Employs many more processors in rural areas • Cheaper alternative for poorer consumers • Highly flexible in adapting to changing market conditions (many disassociated actors along the value chain) • Potential to improve quality products exists—but more challenging • Large multiplier effects (many millers, traders, and farmers)	• More efficient for maintaining consistent quality, grades, and standards—and for branding • Higher milling capacity for supplying premium-grade rice. In Asia, it is the sector commonly producing high-premium-brand rice varieties for export (for example, basmati and jasmine) • Better access to credit for capital improvements (including via subsidies) • Can potentially displace imports, but not totally

Source: Authors' compilation based on observations from field interviews and the literature.

The small to medium milling sector is not without its own challenges. One obvious challenge is the necessity of dealing with many producers, traders, and processors who have wide-ranging skills, access to technologies, and credit, and who interact only at the point of sale or for servicing. As a fragmented processing and marketing system, it has limited abilities or incentives to upgrade to better technologies, marketing, and branding, especially in the downstream part of the value chain. Relatedly, it is absent any consistent grades and standards, exhibits poor record keeping, and has poor organizational capacities. Because most of the millers mill paddy for a fee, they simply leave it up to the traders or consumers who seek their service to worry about quality. While they may wish to invest in modern equipment, many of the smaller-scale operators have poor access to credit to afford the investment. Even among the medium and larger-scale operators, access to credit has not necessarily led to investments in modern equipment. Based on their surveys in Nigeria, Lançon et al. (2003b) found that many of the larger-scale operators were not investing in upgrading their equipment because of uncertainties about paddy supply.

Box 3.1—The experience of Olam in Nigeria

As a major importer in Nigeria that holds one of the largest market shares, Olam has in the past invested to process local rice using large modern rice mills. In 2006, the firm entered into a partnership with USAID (the US Agency for International Development) to establish an outgrower system with smallholder rice producers in order to promote local Nigerian rice production. The program allowed farmers to access technologies, credit, and technical assistance to produce quality premium rice and have assured markets and prices. Productivity and incomes reportedly more than doubled in the first year—encouraging a Nigerian commercial bank (First Bank) to become a major stakeholder in a smallholder farmer commercial credit program.

Unfortunately, the program was discontinued after 2008, when it became unsuccessful in securing a price guarantee and sufficient quantities of paddy in competition with other paddy buyers in the area. Evidently, Olam's initial effort at procuring paddy from outgrower systems proved too risky given global price uncertainties and the logistical costs associated with maintaining varietal quality, input delivery, credit repayments, and sufficient volumes of rice each season.

By 2012, Olam had started venturing into rice production (its first in Nigeria), putting up $49.2 million (N 7.675 billion) into rice farming and a milling facility in Nasarawa State. The rice farm is intended to irrigate up to 6,000 ha of rice to supply up to 60,000 tons of paddy annually for the company's processing facility. The paddy is expected to be converted into about 36,000 tons of milled rice annually.[a] Olam expects to focus attention on milling two premium paddy varieties in Nigeria (FARO 44 and FARO 52) and expects to get about 65 percent of paddy needed from its own farm and the rest from outgrower cooperative agreements with smallholder farmers.[b] How it will successfully manage the latter scheme based on its experience is not certain.

Source: Authors' compilation.

Summary Conclusion

The poor performance of the Nigerian rice value chain relative to that of Asian countries leaves a lot of room for improvement. Yields are not achieving their maximum attainable potential—not because of a lack of improved seeds but due to limited access to and inefficient use of complementary technology inputs such as fertilizers, land cultivation techniques, weeding, and water control. Part of the problem has been high costs of inputs, especially hired labor, fertilizers, chemicals (herbicides and insecticides), and mechanized implements (tractors and tillers). Per-unit costs and margins for production, milling, trading, and marketing are very high relative to those in Asia. Costs are especially high—as much as 50 percent above those of smaller millers—for the larger mills, which often have to operate below capacity and seek paddy from further afield. The small to medium milling sector, in particular, is positioned well to improve, given sufficient investments and training to upgrade its equipment, undertake further processing (such as de-stoning and polishing), and improve trader and market linkages, both upstream and downstream. Doing so has the added advantage of contributing to the transformation of the rural economy, given its scope for generating incomes and employment as well as ensuring affordable food prices for the majority of consumers. We now turn to examining this potential in more detail in the next section.

4. ANALYZING THE POTENTIAL TO INCREASE COMPETITIVENESS[21]

To grow the Nigerian rice economy and ensure rice self-sufficiency, the rice sector must not only have the potential to rapidly expand production, but it must be able to do so in a way that improves the performance and infrastructure of the entire value chain, from farm level to retail markets. The previous section noted the current poor state of production and processing among the majority of smallholder farmers and small millers in the country. Achieving self-sufficiency in rice will mean tapping into the country's biophysical potential, gaining access to modern technologies, expanding the choice of quality rice varieties grown (such as long-grain), and boosting the ability to process and bag premium-quality domestic rice during postharvest. We assess this potential in this section.

Potential to Accelerate Production Growth

In order to design appropriate rice policies, it is important to first understand rice production potential from the biophysical perspective, involving such factors as solar radiation, temperature, rainfall, soil nutrients, and water availability. We assess such biophysical rice production potential in Nigeria using various simulation models including the Spatial Production Allocation Model (SPAM) from IFPRI, Global Agro-ecological Zones (GAEZ), and a cropping system model. Appendix B provides more detail on the simulation methods. We specifically assess (1) how much area suitable for rice production is potentially available in Nigeria and (2) how much rice yield and production would increase if more improved seeds, nutrients, and water were used for production.

Areas with high and medium suitability for rice and actual rice production within these areas are summarized in Table 4.1. Suitability here is determined by the proportion of agronomically attainable yield to maximum potential yield given solar radiation and temperature, where the former is lower than the latter due to agroclimatic constraints of moisture stress, pests and diseases, and workability for each crop in each length-of-growing-period zone (FAO 1996). Rice suitability is estimated by GAEZ (Tóth et al. 2012).

The area suitable for rice production stretches across most of the country. Areas with high and medium suitability for rice production are approximately 4.2 and 26.8 million ha, respectively, in Nigeria. Only 68,000 ha and 3,000 ha are currently under rainfed and irrigated rice production, respectively, within the high-suitability zone, and 843,000 ha and 103,000 ha, respectively, in the medium-suitability zone, based on the assessment from SPAM.[22] Much of these areas suitable for rice production are currently uncultivated. In terms of land, Nigeria has a vast potential to increase rice production.

We then assess the rice yield and production potential achievable under different levels of input intensities in areas with different rice suitability. Input intensity is defined here as the level of adoption of improved varieties, increased application of nitrogen, and use of irrigation. Specifically, we simulate the rice yield and output under three cases: (1) increased use of improved varieties; (2) increased use of improved varieties and application of nitrogen; and (3) increased use of improved varieties, application of nitrogen, and irrigation. In (1) and (2), we simulate only the yield change from the baseline without changing cultivated area (both rainfed and irrigated). In (3), we also assume that irrigation area expands either by replacing some of the current rainfed rice area or by expanding rice to areas where currently other crops are irrigated.

[21] This section authored by Hiroyuki Takeshima, Michael Johnson, and Jawoo Koo.
[22] See Appendix B, for an explanation of adjustments made in the estimated irrigation area.

Table 4.1 Rice production potential: A suitability assessment

Category	Area ('000 ha)		Rice output ('000 MT)	
	High-suitability area	Medium-suitability area	High-suitability area	Medium-suitability area
Rainfed rice	68	843	96	1,162
Irrigated rice	3	103	11	403
Other crops	1,231	1,231		
No crops	2,871	24,617		
Total	4,173	26,794		

Sources: Spatial Production Allocation Model, Global Agro-ecological Zones model, Global Map of Irrigation Areas (University of Frankfurt 2012), and various literature.

Notes: The suitability here is for dryland rice, which is generally higher than but correlated with the suitability for wetland rice. "High" suitability consists of *very high* and *high*, while "medium" suitability consists of *good* and *medium* as defined in the Global Agroecological Zones (GAEZ) model. MT = metric tons.

Key assumptions used in the simulations are summarized in Table 4.2. For the baseline scenario, we assume the following: In the rainfed area, 50 percent of the land utilizes improved-variety seeds (IR-8 type) and 50 percent applies the traditional variety, while for the irrigated area, only improved-variety seeds are used; the rate of nitrogen applications in nutrient quantity (kg/ha) are 56 (rainfed north) and 8 (rainfed south) where improved varieties are grown, and 0 where traditional varieties are grown, while they are 64 and 95 for irrigated north and irrigated south, respectively; area under irrigation is 10 percent, as mentioned above.

The share of improved seed varieties is approximated from Ojehomon et al. (2009) based on the National Rice Survey collected in 2009 and applied to the rainfed area. Although their estimate of almost 50 percent share of improved varieties may be high, using a high share in the baseline allows us to obtain more conservative estimates of the yield and production potential, which is also important given the shortage of accurate information. The nitrogen application rate is estimated for the north (North West, North East, and North Central geopolitical zones) and south (South West, South South, and South East zones) using *Nigeria's Living Standard Measurement Survey–Integrated Survey on Agriculture* (LSMS-ISA) (Nigeria, NBS; and World Bank 2011) for both rainfed and irrigated rice area. Due to the lack of information, we assume no nitrogen is applied for traditional varieties, and we adjust the application for improved varieties in the rainfed area accordingly so that the average application rates weighted by the share of improved varieties (50 percent) is the same as the LSMS-ISA estimate.

Table 4.2 Simulation scenarios and assumptions

Inputs	Baseline		Simulation scenarios		
			1: ↑ Improved varieties	2: ↑ Improved varieties ↑ Fertilizer	3: ↑ Improved varieties ↑ Fertilizer ↑ Irrigation
Seeds Share of improved seeds	Rainfed - 50% improved (IR-8 type), 50% traditional Irrigated - - 100% improved		Rainfed - 100% improved varieties in high-suitability area - 75% improved varieties in medium-suitability area - 50% improved (unchanged) in low-suitability area Irrigated - - 100% improved		
Fertilizer Nitrogen, in kg/ha	Rainfed north Improved: 56 Traditional: 0 Irrigated North: 64	Rainfed south Improved: 8 Traditional: 0 South: 95		Rainfed north Improved: 56 Irrigated North: 128	Rainfed south Improved: 40 South: 150
Irrigation Share of irrigation area	10% (Assuming some of the irrigated area is not under a fully developed irrigation system)				21% (By substituting irrigation area for all other crops to rice)

Source: Authors.

In the simulation, we change the quantity of inputs in the following ways: We increase adoption rates of improved seed varieties to 100 percent in high-suitability zones and 75 percent in medium-suitability zones while keeping the rate at 50 percent in low-suitability zones. Increases in nitrogen application rates are simulated within realistic ranges, so that the rates for improved varieties in rainfed south, irrigated north, and irrigated south increase to 40 kg/ha, 128 kg/ha, and 150 kg/ha, respectively, while the nitrogen application rate for improved varieties in rainfed north remains unchanged because it is already quite high for rainfed conditions. The expansion of irrigated area is simulated by substituting irrigated area for all other crops to rice irrigation, where the distribution of irrigated area for all crops is obtained from Global Map of Irrigation Areas (University of Frankfurt 2012). This is under the assumption that the rice irrigation area expansion in the short term is made possible by replacing other crops instead of constructing new irrigation facilities or raising the production intensity in the current rice irrigation area. Table 4.3 summarizes how this simulation changes the irrigated area in each suitability zone (See Appendix B for the detailed methodology). Importantly, most of the expansion of irrigated area would occur in medium- to low-suitability areas, and expansion of irrigated area in the high-suitability zone may be limited, indicating that the expansion of irrigated areas is possible mostly on area that is marginal for rice if it is through the replacement of other irrigated crops.

Table 4.3 Irrigation expansion assumptions

		Rice suitability		
		High	Medium	Low
Baseline ('000 ha)	Total rice area	71	946	573
	Rainfed rice area	68	843	520
	Irrigated rice area	3	103	53
Irrigation scenario ('000 ha)	Total rice area	71	955	662
	Rainfed rice area	67	818	447
	Irrigated rice area	4	137	215

Source: Authors' calculations based on IFPRI Spatial Production Allocation Model, Global Map of Irrigation Areas (University of Frankfurt 2012), and various literature.
Note: See Appendix B for more detail.

Results are presented in Table 4.4 and Table 4.5. Table 4.4 shows the average yield in each suitability zone. The first two scenarios affect only the rainfed rice yield, while the third scenario affects the irrigated rice yield. The rainfed rice yield in the high-suitability zone increases from 1.4 to 2.1 and 2.4 tons/ha through increased adoption of improved varieties and through improved varieties plus nitrogen application, respectively. Similarly, rainfed rice yield increases from 1.4 to 1.7 and 2.0 in the medium-suitability zone, while the yield change is minimal in the low-suitability zone. The rainfed yield in the high-suitability zone is comparable to that of some Asian countries.

Table 4.4 Rice yields under different technology inputs

	Rice suitability		
Category	High	Medium	Low
Current area ('000 ha)	71	946	573
Average yield (metric tons / ha)			
Baseline, rainfed	1.4	1.4	1.2
Seeds simulation, rainfed	2.1	1.7	1.2
Seeds + fertilizer simulation, rainfed	2.4	2.0	1.2
Seeds + fertilizer simulation, irrigated	5.8	5.5	4.7

Source: Authors' calculations based on cropping system model.

Table 4.5 Rice outputs under different technology inputs (million metric tons)

Category	High suitability	Medium suitability	Low suitability	Total
Baseline (current)	0.11	1.57	0.77	2.45
Seeds simulation	0.15	1.84	0.77	2.76
Seeds + fertilizer simulation	0.18	2.25	0.88	3.31
Seeds + fertilizer + irrigation expansion	0.19	2.37	1.41	3.97

Source: Authors' calculations.

Table 4.5 presents the simulated increase in outputs, aggregating rainfed and irrigated areas. The production is expected to increase from 2.45 to 2.76 million tons through increased adoption of improved seeds, 3.31 million tons through increased use of improved seeds and nitrogen application, and 3.97 million tons through improved seeds, nitrogen, and irrigation expansions. Although the production increase is substantial, the increased production is still likely insufficient to replace the current rice imports of 2 million tons.

Overall, two important messages emerge from the analysis of biophysical potential of rice production in Nigeria. Given the vast areas that are suitable for rice production but currently uncultivated, Nigeria has enough biophysical capacity to be self-sufficient in rice. The increase in yield and production realized from increased use of improved seeds and fertilizer combined with irrigation expansion may also be substantial. However, in the short to medium term, increase in domestic production is unlikely to be sufficient to replace the current 2 million tons of rice imported.

Identification of Competitive Rice Producers

The previous section showed that Nigeria has sufficient biophysical potential to increase rice production. The rice sector in Nigeria, however, consists of diverse types of rice producers, and not all of them are in a position to realize such potentials. It will be important to identify the competitive rice producers in Nigeria who are likely to respond to an improved production environment brought about by government policy and thus have the incentives and capacities to realize the production potential. Their characteristics can guide the government in deciding what types of rice producers should be promoted and scaled up. The current share of such types of producers can also inform the level of aggregate supply response.

Different types of rice producers can be identified through cluster analysis methods. Details of the methodology are provided in Appendix C. Major characteristics of each type of rice producer are summarized in Table 4.6. First, 78 percent of rice producers are market oriented, while 22 percent are subsistence farmers. Second, among market-oriented producers, a small share of two types of competitive producers are also identified, namely small-scale intensive irrigators and mechanized producers, accounting for 7 and 5 percent, respectively, of total rice producers in Nigeria. Other market-oriented producers are less input intensive, with smaller rice production per household farm.

Small-scale intensive irrigators are those who typically operate on one-acre plots and practice labor- and input-intensive rice irrigation. They are often located within canal irrigation systems relatively close to dams in the North West, North East, or North Central geopolitical zones. In LSMS-ISA data (Nigeria, NBS; and World Bank 2011), many of them are found in Gbako Local Government Area (LGA) in Niger State and Kebbe LGA in Sokoto State. These producers enjoy a higher farmgate rice price and cheaper labor and sometimes practice mechanized land preparation. There are approximately 68,000 producers of this type in Nigeria, who produced 89,000 tons of rice in the 2010 rainy season and sold more than half their harvest.

Mechanized rice producers typically use tractors on their plots and use modern inputs (fertilizer, chemicals) intensively, together with some irrigation. In LSMS-ISA data (Nigeria, NBS; and World Bank 2011), some of them were found in Donga and Lau LGAs in Taraba State and in Patigi LGA in Kwara State. There were approximately 51,000 producers of this type in the country, who produced 108,000 tons of rice in the 2010 rainy season.

Table 4.6 Characteristics of major rice producer types

Category	Subsistence producers	Other market-oriented producers	Small-scale intensive irrigators	Mechanized producers
% share among all rice producers	22	66	7	5
Real wage (daily wage / rice price ratio)	13	23	9	20
Farmgate rice price (US$/kg)	45	51	59	43
Fertilizer (US$/ha)	13	27	27	67
Chemicals (US$/ha)	11	11	24	67
% using tractor	13	10	10	100
% using irrigation in diverted stream	3	0	100	42
% with nonfarm income source	51	54	78	80
Household nonfood expenditure (annual US$ per capita)	77	45	75	111
Household assets (US$)	347	337	247	738
Distance to the nearest dam (km)	60	62	24	140
Farm size for all crops (ha)	0.7	0.7	0.5	3.0
% in North zone	70	73	89	0
Rice harvest per farmer (tons)	0.4	1.0	1.3	2.1

Source: Authors' calculations based on cluster analysis.

Characteristics of rice producers indicate both potentials of competitive rice producers and challenges in scaling up production. While intensive irrigated rice production (based on a double season) is possible if labor is abundant, and intensive use of fertilizer and improved varieties are potentially profitable for such farmers, labor is often scarce in rural Nigeria and likely to be a constraint in many locations, and it is important to provide profitable varieties that attract a higher farmgate price. While mechanization is also a possibility for competitive rice production, this option may not be applicable, at least in the short to medium term, for the majority of rice producers, who are poor in both assets and income.

Substantial rice yield growth is, however, still possible in West Africa. Irrigated rice production in the Kpong Irrigation System (KIS), Ghana, provides a useful example (Takeshima et al. 2012) that some parts of Nigeria can follow. In the KIS, rice production realizes on average 5.5 tons/ha of yield (in dry paddy), growing highly profitable aromatic varieties of rice, using 500 kg of fertilizer per ha and intensive mechanization (all land is prepared with power tillers and 60 percent of area is harvested with harvesting machines) and irrigation. Exploratory reviews indicate that the public sector provided key initial support such as crop husbandry knowledge, extension training, subsidized power tillers, irrigation, and road infrastructure in the area, as well as a selection of profitable varieties and on-site production of certified seeds. These critical supports led to the evolution of a profitable rice production system that attracted the private sector to engage in providing credit services, rice processing, mechanization of harvesting, and irrigation facility maintenance. The high profitability of the system has also enabled farmers to offer high wages, which alleviated the labor constraints that often hamper the intensification of rice production. Rice producers there appear even more advanced than the above two types of competitive rice producers identified for Nigeria. Although more rigorous investigation is needed to fully understand the determinants of success in the KIS, it still offers one feasible direction to grow a competitive rice sector in Nigeria.

Improving the Performance of Rice Processing and Marketing

Improved performance of the rice value chain will depend not only on increasing the productivity of paddy production but also on two other things: (1) the rice variety grown (for example, long-grain quality) and (2) the ability to process and bag premium-quality domestic rice during postharvest in order to compete more effectively with imports. Here we focus attention on assessing the most viable options to transform and improve performance of postharvest processing and marketing.

Efficiency of Small versus Large Milling Channels

In assessing the performance of the postharvest rice value chain in Nigeria, a key question that arises is the relative economic efficiency of the small versus large milling channels, as illustrated earlier in Figure 3.1. To measure the economic efficiency of both channels, we draw on the arguments used by Timmer (1998). In his seminal study for Indonesia, he showed that small mills were more efficient than larger milling operations because of the combination of higher capital-to-labor price ratios, lower paddy-to-milled conversion ratios, higher milled-to-paddy price ratios, and higher economic discount rates that are typical in a developing-country setting.

The paddy-to-milled conversion ratio measures the technical efficiency of the mill and can affect the ability of a mill to compete if the milled-to-paddy price ratio is small due to cheaper imports, for example. This situation can be especially challenging for large-scale millers, who typically have added costs associated with procuring quality paddy and further processing unless they are able to capture a price premium on the quality of their brand. Moreover, because mills are capital-intensive enterprises that rely more on capital inputs than labor, the capital-to-labor price ratio and discount rate are just as important in determining their economic efficiency and competitiveness. Naturally, they are more competitive when they operate under conditions of lower per-unit capital costs relative to wages. A key factor that can lower this ratio is the rate at which capacity is being fully utilized, given the scale economies of this heavily capitalized industry. As pointed out earlier, the underutilization of large mills is a common problem in Nigeria and other developing countries where the supply of sufficient quantities of paddy is not always guaranteed. Another key factor is the economic discount rate, which simply measures the rate at which future costs and benefits are discounted relative to the present. Since large mills have higher up-front investment costs and larger benefits accruing in the future than smaller mills, a high discount rate makes the large mills less attractive than their smaller counterparts, because the present value of all future benefits is far outweighed by the total costs, translating into a negative return on investment. Under the same conditions, the smaller mills, on the other hand, would be more attractive since they are less capital intensive and incur only higher wage costs in the future.

Table 4.7 provides estimated values of each of these indicators across three countries: Nigeria, Thailand, and Bangladesh. Derived from mostly anecdotal evidence, it is meant to be indicative and for discussion purposes only. The comparison with Thailand and Bangladesh allows for consistency with the previous assessment of value chain performance. As seen in Table 4.7, Nigeria is evidently less efficient in milling technologies and practices, considering its lower paddy-to-milled conversion ratio and higher milled-to-paddy ratios, in addition to the higher per unit operating costs previously shown in Figure 3.3. A large wedge between paddy and milled rice prices is an indication of higher operating costs and margins for processing and marketing. It can also have the effect of introducing greater profit risks for millers and middle traders as larger price swings are possible within this price band. This is possibly one reason why many small millers in Nigeria operate only on a fee basis. Even among those who buy paddy to resell as milled rice, according to Lançon et al. (2003b), the probability of making a profit was only 40 percent.

Table 4.7 Key parameters affecting profitability of small- versus large-scale rice milling

Measurement (averages)	Nigeria	Thailand	Bangladesh
Paddy-to-milled conversion[a]	0.58	0.66	0.63
Milled-to-paddy price ratio[b]	1.7 / 2.1	1.9	1.2 / 1.7
Capital-to-labor price ratio[c]	2.7	1.6	2.1
Discount rate[d]	10.1	6.7	13.1

Sources: Authors' calculations based on various sources of data, including (for Nigeria) authors' field visits in Niger State and estimates by Chemonics 2009; (for Thailand) Maneechansook 2011 and FOB data from the Thai Rice Exporters Association for "parboiled rice 100%" (www.thairiceexporters.or.th); World Bank Development Indicators; FAOSTAT (FAO 2012); and IMF 2012. [a] For Thailand, source is Titapiwatanakun 2012; for Nigeria, Lancon et al (2003b); and for Bangladesh, Minten, Murshid, and Reardon 2013.

Notes: The four indicators here are those highlighted by Timmer (1998). All values use constant 2005 US dollars and are averaged across three years, 2005–2007.

[b] This refers to the same data in Figure 3.3. The two numbers represents a distinction between standard-quality rice for the first number (the most common quality level of domestic rice) and the higher-quality, premium rice for the second number (usually processed by the large, modern, industrial rice mills).

[c] This is the ratio of total value of agricultural capital stock per agricultural population (US$/person) over the agriculture gross domestic product per agricultural population (US$/person).

[d] This is an annual average interest rate between 2010 and 2012 from the International Monetary Fund statistical database (IMF 2012). Because some banking discount rates were higher than lending rates, we chose to use the former in Nigeria. For Thailand and Bangladesh, in order to be as conservative as possible, we chose the lending rate.

A comparison of price ratios with the average discount rate in each country reveals that Nigeria and Bangladesh face higher investment risks from introducing capital-intensive modern rice mills (MRMs) relative to Thailand. Additionally, for Nigeria, the fact that large mills typically have to operate at well below capacity due to insufficient paddy supply implies much higher per-unit operating costs. The logistical costs and uncertainty associated with procuring the paddy from year to year presents an even bigger challenge in keeping operating costs down. In contrast, the dominant smaller-scale milling sector faces lower operating costs and thus has the potential to realize quick positive returns from simply upgrading postmilling activities for de-stoning, polishing, and packaging. The potential to do so exists, considering the current large price premium between the standard and premium brands of domestic rice.

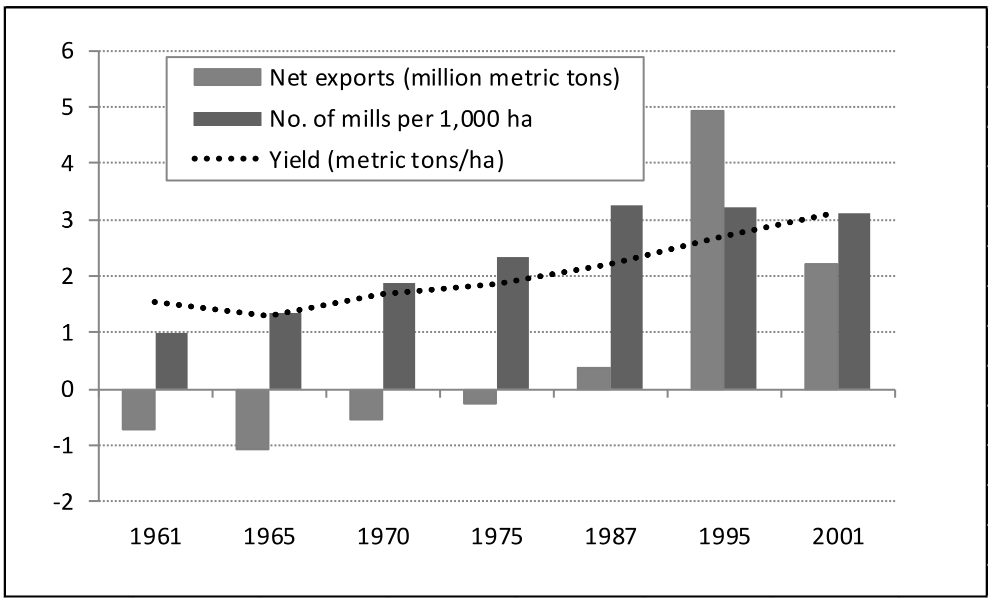
Between the two main channels, therefore, while the large milling channel can produce a premium-quality rice brand that is substitutable with imports, it will always face the challenge of guaranteeing a constant supply of quality paddy while its primary consumer base will be limited to high-end urban markets. Additionally, it will likely rely on continued government support for ensuring paddy supply, capital investments, and protection from cheaper but quality import brands. This will all come at a high economic cost. On the other hand, a strategy that places more emphasis on improving the smaller milling channel will help to meet a broader demand base while at the same time contributing more to the creation of jobs and rural economic transformation. Here, lessons from Asia and elsewhere in West Africa from past efforts to promote large scale MRMs will be useful to review.

Deriving Some Policy Lessons from Asia and Elsewhere

In much of Asia, where rice is a food staple, the rice milling industry grew over time in tandem with the growth in paddy production. Figure 4.1 illustrates this growth for India, showing that as yields grew over time, the number of mills (whether small or large) also expanded per unit area. It is also interesting to note how the growth in rice production in India eventually led the country to switch from being a net importer to a net exporter—which would only have been made possible by an expansion of the country's milling capacity for premium-quality rice destined for export markets (for example, basmati rice). Indeed, the country experienced a phenomenal growth in the utilization of large MRMs in the 1980s and 1990s, reaching a number of about 35,000 in total by 2001 (Harriss-White 2005). However, MRMs never completely displaced traditional practices of parboiling, sun-drying, and using rice hullers, which continued to exist alongside the MRMs. MRMs were instead the preferred choice for milling higher-quality rice destined for export markets in both India and Thailand.

Large industrial MRMs easily handle large volumes of paddy for supplying export markets. A disadvantage of their use for domestic markets is that they often face the risk of operating below maximum capacity as they seek to procure sufficient supplies of paddy destined for domestic markets each year from thousands of smallholder farmers. Therefore public-sector interventions are often needed to ensure that MRMs can continue to operate profitably by assisting with the procurement of paddy, guaranteeing rice purchases directly from mills (for example, for government-managed stocks), or both. In fact, much of the growth in MRMs in India did not occur without government support in the form of credit subsidies to promote investments in building large mills and in procuring the paddy (Harriss-White 2005). Other incentives were also introduced, such as imposing an outright ban on the use of existing small-scale mills based on the traditional huller, establishing rice procurement agencies, instituting quality standardization agencies at the state level, and maintaining a minimum price guarantee for paddy (Shwetha 2010). Today, the Indian government continues to provide both logistical (warehousing and procurement) and price support mechanisms for technology upgrading. Over time, these practices have introduced high fiscal and economic costs as paddy farmers and the MRM industry have grown to rely heavily on such support. At the same time, the small and traditional millers have continued to flourish despite efforts to ban them. In fact, they still contribute a significant share of total milled rice in India (Harriss-White 2005).[23]

Figure 4.1 Evolution of modern rice mills, yields, and net exports in India



Sources: For number of mills, Nayak 1996 and Harris-White 2005; for yields and net exports, FAOSTAT (FAO 2012).

In contrast to India, the public sector in Thailand has not been as heavy-handed with subsidizing MRMs directly, many of which are in the export sector and privately owned. Instead, the government has typically intervened by introducing price support mechanisms for paddy to ensure a steady supply to the milling sector and, ultimately, to exports. The program is popular among politicians because it helps to garner votes among farmers and millers, who represent a large part of the population and benefit the most from the policy (Forssell 2009). Referred to either as the “rice mortgage scheme” or the “pledging program,” the policy enables farmers to sell their paddy to the government via millers participating in the

[23] The ban was finally lifted in 1996 (Harriss-White 2005).

program at more favorable prices should market prices fall below a guaranteed price—thus benefiting both farmers and millers (Titapiwatanakun 2012). A key challenge of the policy happens whenever the guarantee price is set higher than the market price, leading to higher domestic prices and higher holdings of government rice stocks, something that occurred in 2010, when government-owned stocks reached 5 million tons (Thongrattana 2012). Because the policy of accumulating stocks is fiscally costly and can threaten Thailand's ability to compete more effectively in international markets over time, the government has since discontinued the program and slowly begun to release the accumulated stock. In its place, a new price guarantee program has been introduced, but this time it does not involve the direct purchase of paddy from farmers (Thongrattana 2012).

One important lesson from both India and Thailand is the failure to completely displace small- and medium-scale milling operations with large MRMs. This seems to be a general pattern elsewhere in developing Asia. Timmer's (1998) example for Indonesia, referred to earlier, provides a good explanation for this phenomenon by showing how small mills are both socially and privately profitable compared with larger mills in supplying domestic markets. Not only do they have lower per-unit operating costs, but they also do not displace rural employment, especially female labor. Although the study was carried out decades ago, Timmer's (1998) findings continue to be relevant today. Both India and Thailand have witnessed the maintenance of a vibrant small milling sector that supplies domestic markets alongside larger MRMs that have emerged to serve high-end urban and export markets.

The experience in West Africa in general has not been very different from Asia's except in the context of being a net importer. Large MRMs were initially introduced with heavy state intervention as part of the import substitution strategies of the 1970s and 1980s. But these would collapse in due course as governments withdrew their support under a broad sweep of structural adjustment and market reform efforts in the 1990s. The experience in Mali is a particularly good example. After the government sold off several large mills in Office du Niger to private operators and lifted a ban on small-scale milling, the large operators suddenly found themselves unable to compete effectively with the small milling sector in procuring paddy (Diarra et al. 1999). The latter was well positioned to operate more efficiently and flexibly with smallholder suppliers. At the time, according to Diarra et al. (1999), per-unit costs for large millers turned out to be about four times those of smaller mills (17.6 versus 4.3 West African CFA francs) because the large mills typically operated at well below capacity. This is not too different from the experience in Nigeria.

The Emergence of More Sophisticated Markets

The conditions Timmer (1998) analyzed for Indonesia decades ago remain quite relevant in Nigeria today, as they have in Asia. However, conditions may be changing as urban populations and incomes continue to grow in both Asia and Africa. New research evidence shows demand shifting toward higher-quality and premium milled rice in Asia's emerging sophisticated urban markets (Minten, Murshid, and Reardon 2011, 2013; Murshid 2011). In response, the postharvest rice sector has been transforming itself by adopting larger MRMs. While past adoption of higher-yield paddy varieties has certainly helped to meet the growing demand, the increased adoption of MRMs is proving more critical in meeting the demand of these new domestic markets. In some locations in Bangladesh, for example, MRMs now produce more than 90 percent of the rice marketed from the local area, according to observations by Murshid (2011). Their presence is increasing not only the milling capacity but also the quality of rice produced in the area. This shift has also led to more sophisticated institutional and marketing arrangements that involve middlemen brokers who link paddy traders with millers and the latter with rice traders and wholesalers. These actors capture a larger share of the price premium for the higher-quality rice, while farmers benefit the least (Minten, Murshid, and Reardon 2013). Clearly, as demand for premium-quality rice continues to expand in developing Asian countries, local rice economies in the region will continue to witness a transformation toward more sophisticated processing and marketing arrangements. Overall, these changes are having a profound effect on local rice economies. Greater employment opportunities are appearing on the scene—such as subagents for paddy producers and other new trader entrants, medium-scale parboiling and milling firms, mini–drying yards, and new postmilling operations (for example, for puffing)—and the changes are also leading to commodification of specific rice brands and introduction of a system of quality grades and standards (Harriss-White 2005).

Lessons for Nigeria

For Nigeria, similar trends are poised to occur with rapid urban population growth—as is already evident in the dramatic increase of premium rice imports during the last few decades. Unlike in the Asian countries, however, the local rice sector in Nigeria has been ill prepared to respond and adapt to these changing demands. Meeting the demand for higher-quality premium rice with domestic brands, therefore, is feasible in the short run only through promotion and use of the larger MRMs, as the government is already doing. However, the heavy government support that the larger MRMs require to achieve this goal is potentially introducing economic distortions that could undermine the health of the rice sector as a whole. It is unlikely that the large MRMs can be economically efficient in supplying the domestic market given their higher per-unit operating costs, higher capital costs, and limited access to quality paddy, as experiences elsewhere in West Africa and in Asia illustrate. In fact, it is more likely that imports would never be totally displaced while the small milling sector continues to fill the void in supplying the domestic market.

Therefore, while popular attention has been on the establishment of large industrial mills, some serious attention should be given to revitalizing the dominant, smaller milling sector, especially from a public policy perspective. This is a sector that has the potential to improve, given the current cost and price structure it faces along its entire value chain—with the potential to easily absorb 25 percent in increased costs (such as for de-stoning and colorization) to further process and bag better-quality milled rice, as shown in Section 3. The potential is even greater if there is significant improvement in paddy production costs and yields, varieties (such as long-grain), and trader and marketing cost margins. Field observations showed very poor conditions of basic infrastructure such as access to electric power, water, and good feeder road networks. Addressing these basic infrastructural problems, along with improving access to technologies, credit, and storage, will also be critical to upgrading the sector and providing options to smooth out operations outside the typical harvest season. Finally, although it is unlikely that the small milling sector can produce a quality premium brand comparable to that of the larger and more capital-intensive milling sector, it has the potential to produce rice of sufficient quality and at a low enough cost to be able to meet the demand and price preferences of the average consumer.

Summary Conclusion

A number of key messages arise from this review. First, given the vast areas that are suitable for rice production but currently uncultivated, Nigeria has enough biophysical capacity to produce rice. The increase in yield and production realized from expanded use of improved seeds, fertilizer, and irrigation may be also substantial. However, in the short to medium term, increase in domestic production is unlikely to be sufficient to displace the current 2 million tons of rice imports.

Second, focusing on the more market-oriented and competitive farmers in Nigeria can increase the potential for rapid growth. These are the small-scale intensive irrigators and the mechanized producers. Because they currently account for only about 5–7 percent of total rice farmers in Nigeria, the potential to expand this number among many other market-oriented producers who are less input intensive is great indeed. With sufficient intensification through small-scale irrigation and mechanization, rice yields have the potential to almost double to 5.5 tons/ha, as has been witnessed in Ghana, for example. However, the success of these systems in Ghana required extensive public-sector support for crop husbandry technologies, extension services, subsidized power tillers, irrigation, and improved road infrastructure. The selection of high-quality and profitable varieties, including introducing on-site production of certified seeds, also proved important. With the right infrastructure and services in place, the system was able to be profitable for private-sector investors to enter in place of the government in providing services to farmers such as credit, rice processing, mechanization of harvesting, and irrigation facility maintenance. The high profitability of the system has enabled farmers to offer higher wages, which have helped to alleviate the labor constraints that often hamper the intensification of rice production. Although a more rigorous investigation is needed to fully understand the success of this example in Ghana, it still offers one feasible direction to grow a competitive rice sector in Nigeria.

Third, while the production of higher-quality premium rice is feasible in the short run only through the promotion and use of the larger MRMs as the government is already doing, this strategy will require expensive government support that may be detrimental to improving the whole sector in the long run. This is because it is unlikely that the large MRMs can be economically efficient in supplying the domestic market over time. There is a real danger that in years to come the sector would still have to rely on the government to remain competitive, as experiences elsewhere in West Africa and in Asia have shown. Moreover, ignoring the small milling sector could have the opposite of the desired effect, undermining the core goals of the ATA itself—especially the goals of creating jobs and wealth in rural areas. Additionally, the higher prices that result from overprotecting the large MRMs will only hurt poor consumers, who spend a higher proportion of their income on food. More serious attention should be given to revitalizing the dominant small- to medium-scale milling sector, which has greater potential to easily absorb 25 percent in increased costs (such as for de-stoning, polishing, and colorization) to further process the milled rice. This attention to revitalization should also include addressing problems associated with high trader and marketing cost margins.

Finally, if there is a key lesson from the past and from elsewhere in West Africa and Asia, it is that the growth and resilience of small- to medium-scale millers has continued to play a key role in contributing to the growth and transformation of rural economies. Over time, as incomes have risen and consumer preferences have shifted more toward higher-quality rice, the sector has been able to adapt and attract investors along its value chain to upgrade equipment and expand milling capacities. Government support has been critical in the process by providing access to the necessary technologies and training; subsidizing credit and sometimes even the price of paddy; and making investments in infrastructure to lower the costs for energy, transportation, and access to markets and information. With these supports in place, subagents for paddy producers and other new trader entrants have appeared on the scene, including those specializing in postmilling operations such as de-stoning, colorization, and puffing. Eventually, this evolution has led to the commodification of specific rice brands, together with a system of quality grades and standards. While this process can take time, the smaller milling sector in Nigeria is poised to respond, given the right enabling environment.

5. WEIGHING THE FUTURE ECONOMIC COSTS AND BENEFITS OF ALTERNATIVE POLICIES[24]

Given the potential to expand paddy production and improve the rice postharvest sector, we now weigh the potential economic costs and benefits of the alternative policies Nigeria is considering for achieving rice competitiveness and growth. To accomplish this, an economywide multimarket (EMM) model was developed for Nigeria. Similar EMM models have been used for analyzing both a country's and a region's agricultural growth options (see, for example, Diao and Nin-Pratt 2007 for Ethiopia, Nin-Pratt et al. 2011 for the West African region, and Omamo et al. 2007 for the East and central African regions).

In the Nigerian EMM model there are 41 agricultural and agriculture-related sectors, including 26 crops, 5 livestock, 2 fishery products, 8 animal products, and 2 aggregate nonagricultural sectors.[25] The production function for each agricultural and nonagricultural sector is a function of prices. Agricultural production functions are defined at the state level (37 states in total), while for the rice production function, they are further defined by four production systems: upland, lowland, irrigated rice, and all other types of rice production. Moreover, for the crop production sector, both a yield and an area function are explicitly defined. On the demand side, six types of demand are considered: food, seed, feed, processed, waste, and other demands. While food demand for a particular product is a function of prices and per capita income, other types of demand are assumed to be proportional to either own production (for example, seed demand) or the relevant primary production (for example, feed demand proportional to livestock production and processed demand for livestock proportional to meat production). The food demand function for a particular good is defined for rural and urban households separately, and total food demand equals rural and urban demand per capita multiplied by rural and urban population. Domestic price for a particular product is endogenously determined by the equilibrium between domestic supply and demand when such price is a departure from either import or export parities, including import tariffs and trade margins. For the commodities with imports (such as rice and wheat) or exports (such as coffee), the prices are exogenously determined; that is, their prices equal import (export) parities plus (minus) import (export) taxes and trade margins. A detailed description of an EMM model can be found in Diao and Nin-Pratt (2007).

The data to construct the Nigerian EMM model come from various sources: The agricultural production data at state level are from the Nigerian National Bureau of Statistics (NBS) (Nigeria, NBS 2012), while FAO (2012) data are used for those crops or livestock products not included in the NBS data. The two nonagricultural sectors are defined as industry and service value-added using data from the World Development Indicators (2012). Besides rice, the commodity trade data and data for the six types of demand are also from FAO (2012). We use Comtrade data (UN 2012) to calculate rice imports. Finally, we use the 2011 *Nigeria's Living Standard Measurement Study–Integrated Surveys on Agriculture* (Nigeria, NBS; and World Bank 2011) to calculate rural and urban food demand. We chose 2010 as the base year for the model.

The Nigerian EMM model is a policy simulation tool, and the choice of elasticity in both supply and demand functions will affect its result. Ideally, the elasticity should be econometrically estimated using the data from Nigeria. However, with more than 40 agricultural sectors included in the model, it is impossible estimate the supply elasticity econometrically. Therefore we selected a uniform direct price elasticity of 0.2 in the supply function first, and then calculated cross-price elasticity in the same supply function by multiplying its direct price elasticity with the share of a relevant sector's production in the total value of agricultural production.[26] Given the economywide feature of the EMM model, the simulation results are generally not sensible to the choice of the direct price supply elasticity in a range

[24] This section was authored by Xinshen Diao.

[25] The full list of 41 agricultural sectors is provided in Table A.3 in Appendix A.

[26] Choice of a value of 0.2 for the own price elasticity in the supply function is supported by the literature, although there are variations depending on the product (see, for example, Thiele 2000, 2003; Alemu, Oosthuizen, and van Schalkwyk 2003; Abrar, Morrissey, and Rayner 2004; Leaver 2004; and Olubode-Awosola, Oyewumi, and Jooste 2006).

of -50 percent to +50 percent of the value we chose. We use the budget expenditure shares and income elasticities estimated in Section 2 to derive price elasticities of demand, assuming a linear expenditure demand system such that the budget constraint is satisfied for each demand function.

Rice is the focus of the study, and we therefore pay more attention to the design of the rice sector in the model. We distinguish two types of rice, low-quality and high-quality, according to our observations in the country. As discussed in the previous section, many local varieties of rice are less substitutable with imported rice due to their poor quality. Thus, we assume that the low-quality varieties of rice (or standard local rice) are unable to compete with imported rice and their production meets local demand in the domestic market. On the other hand, there are high-quality local rice varieties that are highly substitutable with imported rice (premium local rice). These two assumptions imply that the standard rice type is produced and consumed domestically and its price is endogenously determined by the equilibrium condition in the domestic market, while the price for the premium rice type in the domestic market equals its import parity plus tariffs and market margins, and it is not directly determined by domestic supply and demand. The two types of rice are substitutable in both production and consumption. To capture such substitution, we assume that supply of and demand for both varieties respond to prices for both types of rice; that is, change in the price for the standard rice type affects the demand for and supply of the premium types and vice versa. Given that there are not enough data to identify the production volume of the two types of rice, we arbitrarily assume that high-quality rice is currently produced from 3 percent of total cultivated rice area and the yield of the two types of rice is similar.

Three types of interventions and levels of effort that aim at increasing rice production are designed for the four simulations. The first simulation (S1) focuses on interventions to increase rice yields and to expand the area devoted to high-quality rice varieties, and we define this scenario as a technology change scenario. The second simulation (S2) focuses on interventions to reduce transaction cost and improve market efficiency, and we call it a market improvement scenario. The third simulation (S3) combines S1 and S2. The fourth scenario (S4) is designed as the trade protection policy. In this scenario we increase import tariffs, which leads to a higher rice price in the domestic market and hence to increased rice production. For the different types of interventions, we further consider three different levels of intervention: a minimum, increased, and accelerated level of effort. Table 5.1 summarizes the key assumptions and their three different levels applied under the four scenarios (excluding S3, since it is a combination of S1 and S2).

Table 5.1 Assumptions and targets applied in the Nigerian economywide multimarket model simulations

Scenario		Exogenous parameters shocked in the model	Targeted key endogenous variables in the model	Level of effort for each relevant scenario			
				Base	Minimum	Increased	Accelerated
S1	Technology change—standard rice (low-quality)	Yield growth	Level of yield (MT/ha)	1.9	2.0	2.0	2.1
			% change from base		*2.0*	*4.1*	*6.3*
		Area growth	% of total rice area	97.1	94.9	91.8	85.1
			% change from base		*-3.6*	*-7.0*	*-10.4*
	Technology change—premium rice (high-quality)	Yield growth	Level of yield (MT/ha)	1.9	2.2	2.5	2.8
			% change from base		*10.2*	*21.6*	*34.1*
		Area growth	% of total rice area	2.9	5.1	8.2	14.9
			% change from base		*71.7*	*195.0*	*407.4*
S2	Market improvement	Market margins		70	60	51	43
S4	Import restriction	Tariff rates (%)		50	100	200	400

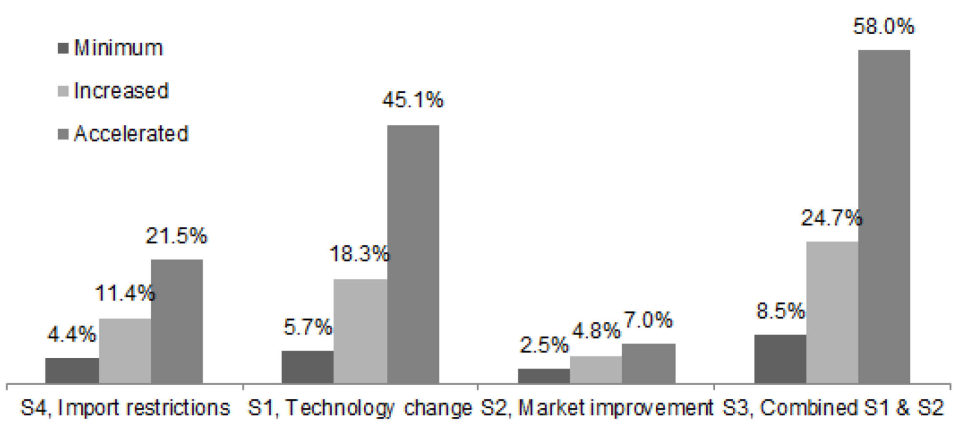
Source: Author's calculations for Nigerian economywide multimarket model simulations.
Note: MT = metric tons.

While the scenarios are designed with rice production as a focus, the EMM model simulations simultaneously solve for the new levels of rice production, imports, prices, and consumption. With the model's economywide nature, production and consumption for the nonrice sectors as well as the aggregated food price index can be affected when household incomes are affected by changes in rice production and rice prices. In the following subsections, we will discuss the EMM model results against the base level for a series of key variables including rice production, consumption, and imports; food price index; total agricultural real income; and household income.

Improving Rice Competiveness: A Win–Win Strategy

The EMM model simulation results emphasize technological change as key for improving rice competitiveness in Nigeria. Figure 5.1 presents the resulting changes in total rice production under each of the four scenarios. For each scenario, results are reported under the three different levels of effort in the intervention: minimum, increased, and accelerated. For example, for the S1 scenario, results are the combined effect of raising rice yields and area cultivated for both standard and premium rice types. For standard rice, yields rise from 1.91 tons/ha to 1.96 tons/ha under the minimum level of effort, to 2.01 tons/ha under the increased level of effort, and to 2.06 tons/ha under the accelerated level of effort. Because we assume that much of the focus of needed public interventions will be for the premium rice type, we assume higher yield and area increases for this variety. For premium rice, yields rise from 1.91 tons/ha to 2.16 tons/ha under a minimum level of effort, to 2.46 tons/ha under an increased level, and to 2.82 tons/ha under an accelerated level. Area is also allowed to expand for premium rice, from a current share of 2.9 percent of total rice area to 5.1 percent under minimum effort, to 8.2 percent under increased effort, and to 14.9 percent under accelerated effort.

Figure 5.1 Change in total rice production under alternative scenarios (% change from base year)



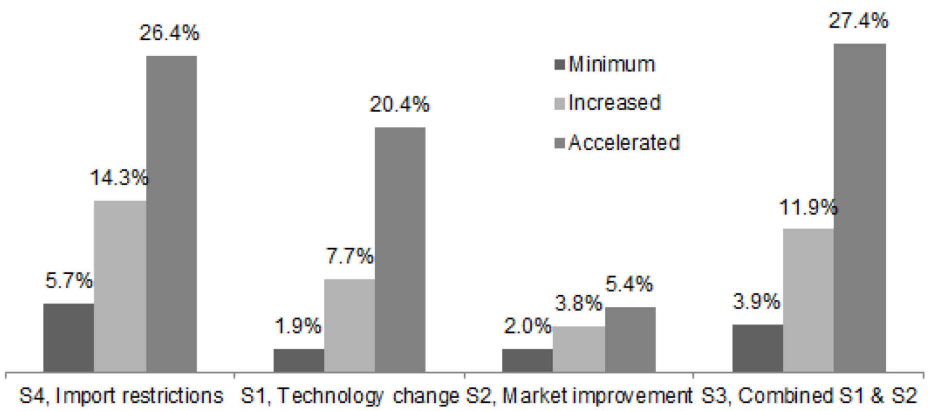
Source: Nigerian economywide multimarket model simulations.

Altogether, results for the first scenario (S1), for example, show that rice production increases by 5.7 percent, 18.3 percent, and 45.1 percent under each level of effort, respectively (Figure 5.1). As shown in Table 5.1 above, assumed yield increases in the model are modest, ranging from 2.6 percent to 48 percent of current level of national average yield, and such a level of yield is achievable if the policies and interventions provide farmers with the right incentives and technology. Also, replacing standard with premium varieties is important for technology adoption, as the demand analysis discussed above shows that income elasticity for imported rice is higher than for local rice for both urban and rural consumers. Premium local varieties can meet such consumers' preferences and hence are relatively easy to substitute for imported rice.

Figure 5.1 also shows the importance of market improvement in combination with the technology intervention. At similar yield and area targets as those under S1 (the technology change scenario), rice production can potentially rise by about 58 percent with accelerated effort when technology is combined with market improvement (S3 in Figure 5.1).

When rice growth strategies are centered on technology change, increased rice production will not be at the cost of reducing production of other crops. This can be assessed by changes in rice production areas under alternative growth strategies simulated in the model. As shown in Figure 5.2, cultivated rice area rises modestly under S1, the technology change scenario. The maximum increase in rice area is 27.4 percent when technology is combined with the market improvement in S3 under accelerated efforts of intervention. We will come back to discuss the impact of tariff policy later.

Figure 5.2 Change in cultivated rice area under alternative scenarios (% change from base year)



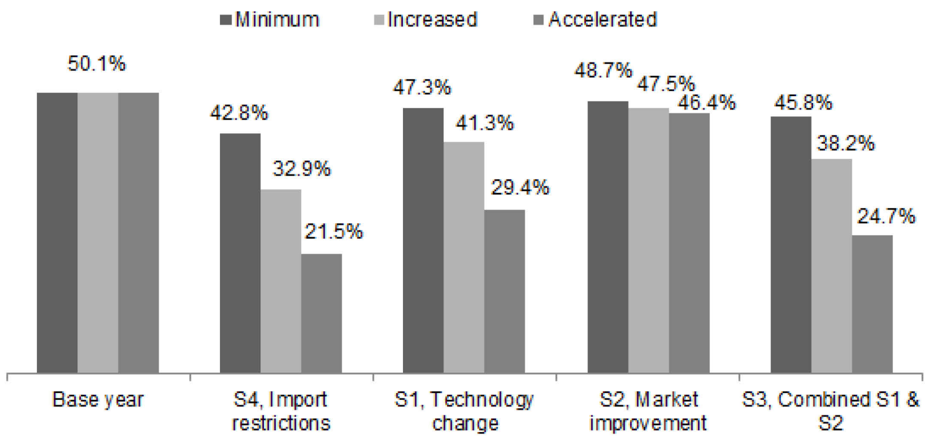
Source: Nigerian economywide multimarket model simulations.

Raising Import Tariffs: Unlikely to Lead to Self-Sufficiency Goal

We now turn our discussion to the import protection policy the government is considering. By reducing rice imports through increasing the tariff rate, the import protection policy is expected to force consumers to substitute imported rice with local rice in their consumption, and producers will have incentives to increase rice production when the border protection makes the local rice price higher than that of imports. Eventually, rice is expected to become self-sufficient when producers continue to increase their production (assuming that consumption will not grow faster than production). Thus, the first purpose of designing an import protection scenario is to assess how high a tariff rate must be to significantly reduce rice imports. Given the elasticity applied in the model, the results show that the import tariff rate has to reach more than 1,000 percent (from the current rate of 50 percent) in order for rice imports to reduce to close to zero. This is an unrealistic option in terms of political feasibility and challenges of implementation. Therefore, we consider 400 percent as the highest tariff rate in the figures presented above and in the following discussion.

Figure 5.3 presents the model results of rice import–consumption ratios under alternative scenarios. In the base year of the model, imports account for about half of total rice consumption in Nigeria. When the rice tariff rate increases to 400 percent (S4 scenario) from the current 50 percent, the rice import–consumption ratio falls dramatically but imports remain at 21.5 percent of total consumption.

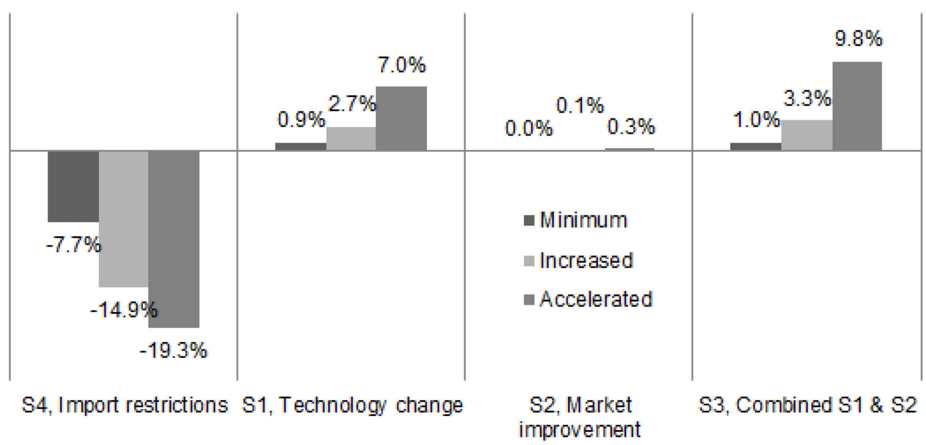
Figure 5.3 Ratio of rice imports to consumption under alternative scenarios (%)



Source: Nigerian economywide multimarket model simulations.

Moreover, as shown in Figure 5.4 (and Figure 5.1), the decline in the rice import dependency ratio is a combined result of increasing rice production and reducing rice consumption; that is, it is at the cost of consumers' benefit. For example, rice consumption is reduced by 19.3 percent with the accelerated tariff rate of 400 percent while it increases by 9.8 percent under the accelerated application of increases in productivity and reduced marketing margins combined. To further understand the relationship between rice production and consumption at different rice tariff rates, we run a series of additional scenarios with different rice tariff rates, ranging from 50 to 400 percent. Figure 5.5 presents their results.

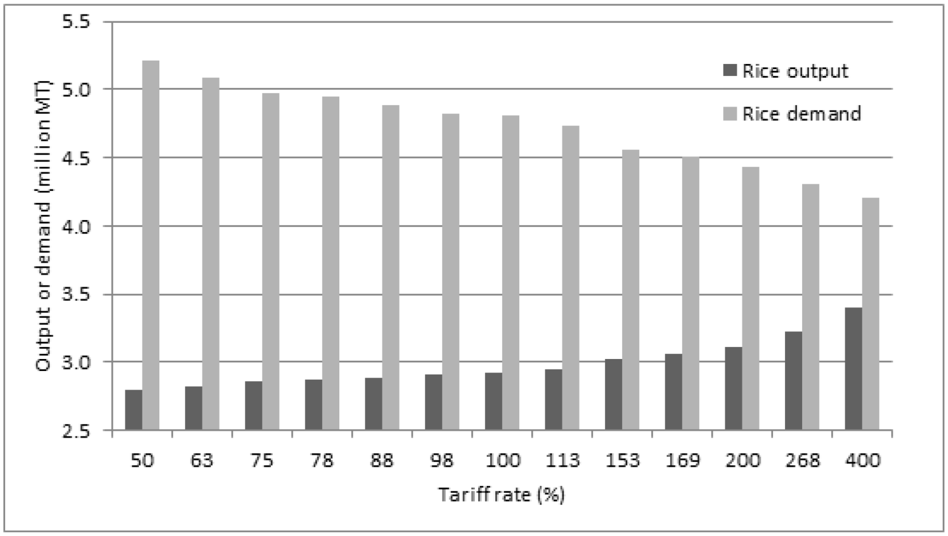
Figure 5.4 Change in rice demand under alternative scenarios (% change from base year)



Source: Nigerian economywide multimarket model simulations.

As shown in Figure 5.5, in the base year, Nigeria needs to consume about 5.2 million tons of rice, of which 2.8 million tons is produced domestically, meaning that about 2.4 million tons are imported. When the tariff rate rises to 100 percent from the current rate, rice production increases only modestly, to 2.9 million tons, while demand falls to below 4.8 million tons. That is to say, each ton of increased rice production corresponds to about 4 tons of decline in rice consumption. At a tariff rate of 400 percent, rice production increases to 3.4 million tons but is still far below the current level of rice consumption (5.2 million tons). Although such a high tariff rate would also reduce consumption as domestic rice prices rise, the fall in demand is not steep enough to make the country self-sufficient in rice production. Rice consumption would decline to 4.2 million tons but remain above domestic production of 3.4 million tons. Thus, under a high tariff policy, the gap between domestic supply and rice consumption would remain, albeit smaller. But even more importantly, the reductions in the size of the gap would be driven mainly by the decline in rice consumption as consumers face big price hikes, particularly in urban markets, where imported rice is mainly traded. The political feasibility of such a policy, therefore, would need to be seriously considered.

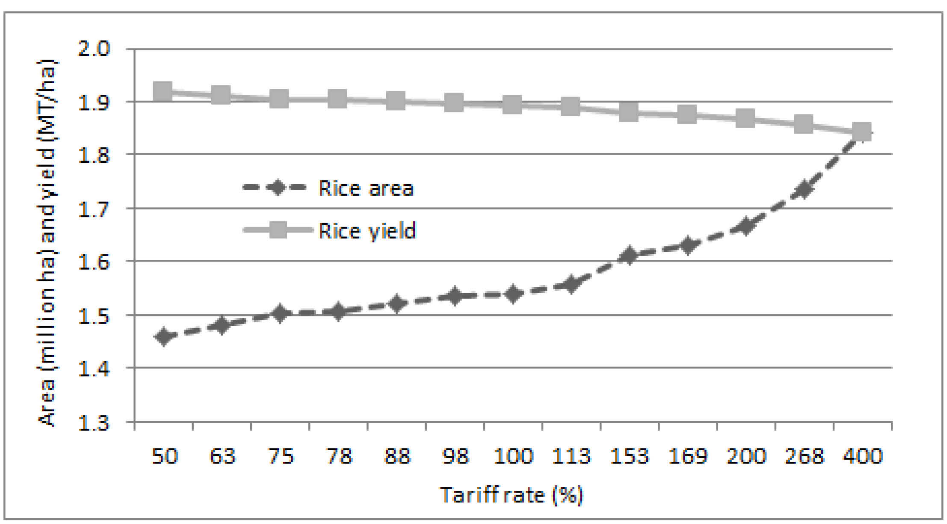
Figure 5.5 Rice production and demand under different tariff rates



Source: Nigerian economywide multimarket model simulations.

Increased rice production under the high tariff policy is not only at the cost of rice consumers but also at the cost of farmers who grow crops other than rice. As shown in Figure 5.6, increased rice production comes from area expansion. With rice production expanded to those areas that were originally used for producing other crops, average rice yield actually falls, given that rice is now being produced on land that is only marginally suitable for rice production (Figure 5.6).

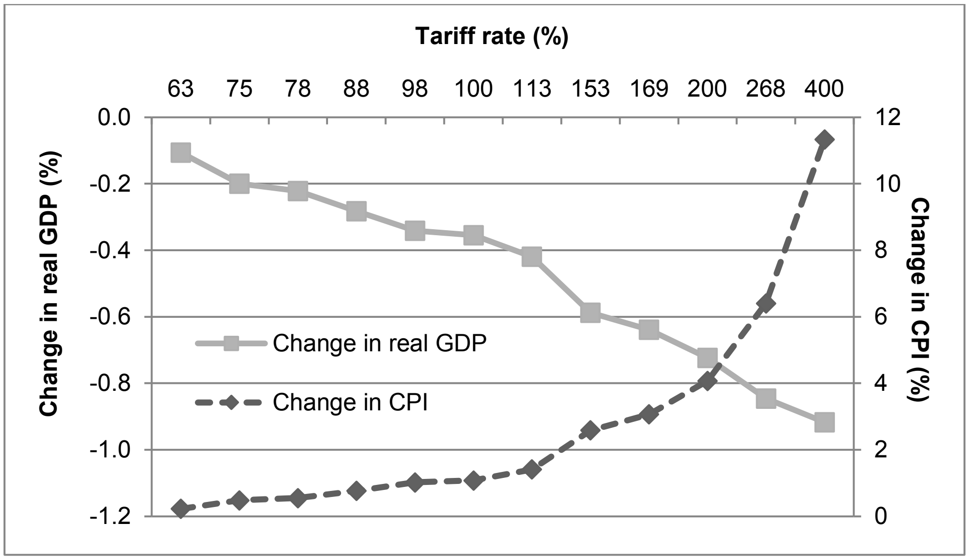
Figure 5.6 Yield and cultivated area of rice under different tariff rates



Source*:* Nigerian economywide multimarket model simulations.

The overall effect of the high tariff policy on the agricultural sector as a whole is negative. As shown in Figure 5.7, with high tariff rates, particularly when the tariff rate is higher than 200 percent, real gross domestic product (GDP) falls and the consumer price index (CPI) rises. At the tariff rate of 400 percent, GDP falls by almost 1 percent CPI rises by almost 12 percent. Given that rice production increases and its contribution to agriculture—and hence to GDP—is positive with high tariff rates, the decline in GDP implies that other agricultural sectors (that is, aside from rice production) and the nonagricultural sector will be negatively affected by the rice tariff policy.

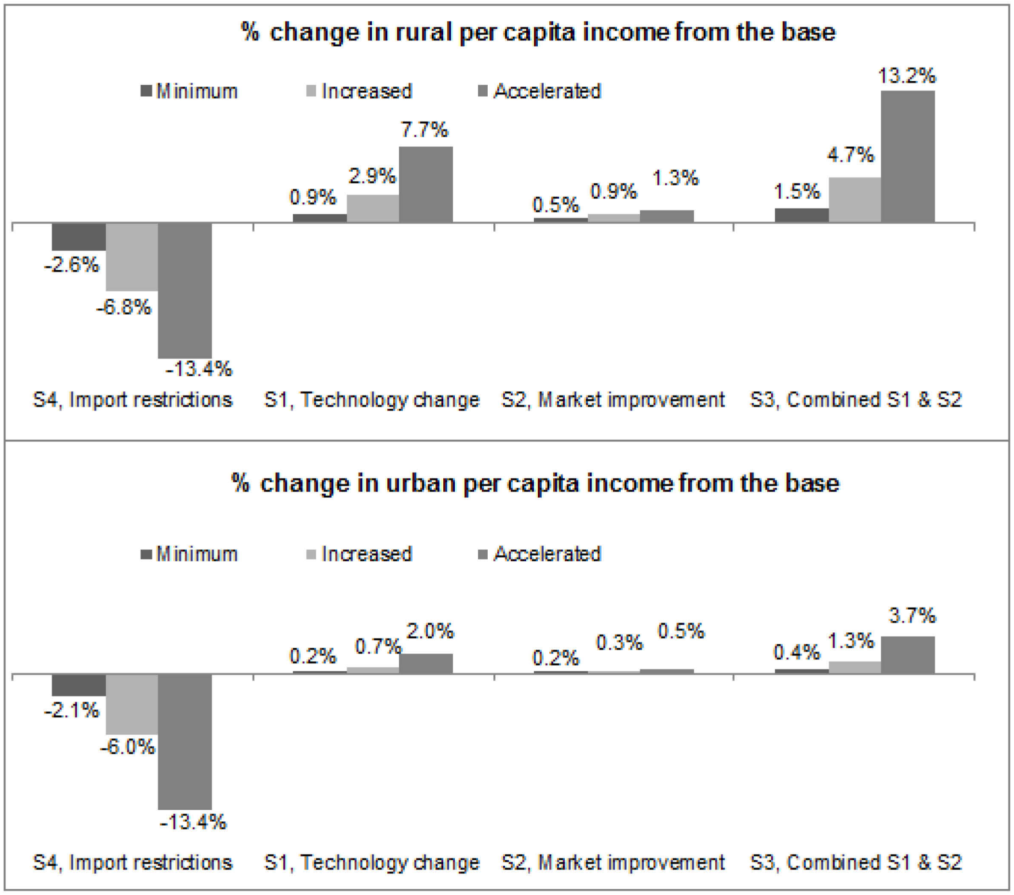
Figure 5.7 Changes in real GDP and food price index under different tariff rates



Source: Nigerian economywide multimarket model simulations.
Notes: GDP = gross domestic product; CPI = consumer price index.

In Figure 5.8, we further assess the impact of alternative rice growth strategies on the incomes of rural and urban households. Such an assessment can better measure the overall welfare effect of different policies. Changes in households' real incomes are measured as their per capita nominal incomes deflated by the CPI in each simulation against their base-year level of per capita incomes. As shown in Figure 5.8, both rural and urban households are hurt by the import restriction policy, and both gain significantly under the policies that promote technology change and improved market efficiency.

Figure 5.8 Changes in rural and urban per capita real income under alternative scenarios

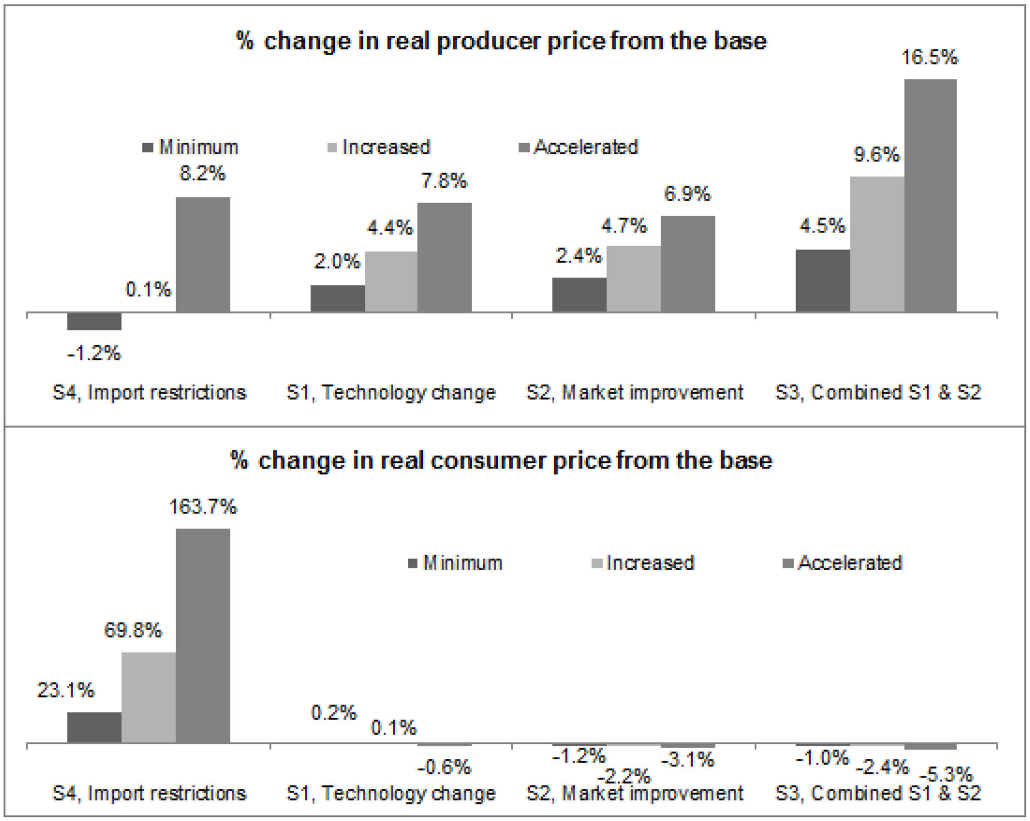


Source*:* Nigerian economywide multimarket model simulations.

For both urban and rural households, the negative welfare effect under the import restriction policy is due to the declines in nominal income and rises in CPI. For example, at a tariff rate of 400 percent, both rural and urban nominal household incomes fall by about 2.1 percent while CPI rises by 11.3 percent. These two factors together cause real incomes to fall by 13.4 percent. Declines in nominal incomes are the result of a fall in agricultural and nonagricultural production. When consumers have to spend more income on reduced amounts of rice and at a higher price, they have to reduce their spending on other agricultural and nonagricultural products. The prices of those commodities produced mainly for domestic markets fall, generating a negative supply response from their producers. On the other hand, the increased CPI is due to the higher rice price, although prices for many nontraded products may actually fall.

When policies are adopted to promote technology change and improve market efficiency under scenarios S1 to S3, both rural and urban households benefit, with rural households benefiting more. Under these scenarios, while CPI also rises, nominal incomes of rural and urban households rise even more. For example, under S3, with the accelerated level of productivity change and reductions in marketing margins, rural and urban households' nominal incomes increase by 19.4 and 9.9 percent, respectively, while CPI also increases by 6.2 percent. As a result, increases in real income turn out to be 13.2 and 3.7 percent for rural and urban households, respectively (Figure 5.8). Figure 5.9 also reports this phenomenon for changes in relative producer and consumer prices. The combined technology change and reduction in marketing margins raises the price received by rice producers while marginally reducing the price consumers pay (both deflated by the CPI).

Figure 5.9 Changes in relative rice prices under alternative scenarios (% change from base year)



Source: Nigerian economywide multimarket model simulations.
Note: The relative price is defined here as the nominal rice price deflated by the consumer price index.

If the tariff policy (S4) is maintained together with the combined technology change and reduction in marketing margins (S3), we would expect the prices consumers pay to be higher but still significantly lower than under the scenario of a tariff regime alone. In this case, the rice import tariff may be justifiable under the *infant industry* argument—especially if such a combination helps to transform the country's domestic rice sector through productivity and output growth. The challenge for the Nigerian government under such a scenario would be both in terms of (1) ensuring consistency in tariff policies (for example, to avoid using tariffs simply as an instrument for domestic price stabilization) and (2) committing public resource allocations to improve the enabling environment to attract private-sector investments and growth in the rice sector.

Summary Conclusion

Nigerian historical data discussed in Section 2 show that import tariffs may not be effective in reducing rice imports and increasing rice production. The modeling analysis further confirms it. In the model the simulation results show that doubling the rice import tariff rate (from 50 to 100 percent) only modestly raises domestic rice production, and at an even higher tariff rate (400 percent), rice production increases by less than 22 percent of current levels. The tariff-induced supply response occurs through rice area expansion without yield growth, which implies that other crop production can be negatively affected. The overall welfare effect therefore is negative, with both rural and urban households hurt by the high import tariffs. Finally, even with reduced consumption caused by the tariff, imports still account for 21.5 percent of total consumption, demonstrating that achieving self-sufficiency through increased tariffs is unlikely to be successful.

The model also simulates alternative rice growth strategies by focusing on technology change and market improvement. The simulation results show that such policy options are win–win strategies. With a modest increase in rice yield, from 1.9 tons/ha to 2.2 tons/ha, together with the expansion of high-quality varieties to replace the low-quality ones, the competitiveness of local rice can increase. In fact, rice production can potentially achieve the same levels as those achieved under a highly protectionist policy. In sharp contrast, however, rice consumption also increases among both rural and urban households, while the import dependency ratio is reduced to about 30 percent (from the current 50 percent). Moreover, the economywide impact is also positive, as other crop production will not be hurt and some crops even benefit from rice growth. When technology change is combined with market improvement, local rice competitiveness increases significantly. Under this scenario, both production and consumption increase while the import dependency ratio falls by half. Income gains go to both rural and urban consumers, including rice producers, while rice growth is not accompanied by domestic food price inflation (of overall food prices) as in the case of the high-protection policy. Alternatively, if the government considers the tariff policy as politically imperative using the infant industry argument, it will be essential to maintain both a consistent tariff policy and public investment allocation commitments in the rice sector in order to attract private-sector investments and productivity growth over the long term.

6. CONCLUSION: POLICY IMPLICATIONS AND DISCUSSION[27]

The principal objective of this paper was to review and assess the policy alternatives and the potential for Nigeria to transform its domestic rice sector to become more competitive with imports and ultimately displace them over time. Two key strategies that have been adopted by the government under the ATA are examined for their potential to succeed and their long-run welfare implications for contributing to this self-sufficiency goal. The first is the introduction of import tariffs in order to make domestic rice more competitive on price alone. The second concerns expanding paddy production and processing of premium-quality rice in order to displace imports over time. In the process, a number of key policy questions were examined, including these: Is there potential for domestic rice production to grow and achieve self-sufficiency in the short to medium term? Is there potential to improve the quality and competitiveness of the final domestic rice product in domestic markets? Are there differential abilities and efficiencies among existing mill types (small to large) for improving quality and meeting demand? Can lessons be drawn from elsewhere in West Africa and Asia? Are the policies being considered by the current ATA sufficient? Will they ultimately lead to displacing imports? What are the alternatives, given this knowledge? We summarize the key results and findings from examining these questions, followed by a discussion of their policy implications in the context of the ATA strategy.

Summary of Results and Findings

A number of key messages emerge from the results and findings in our analysis. First, while Nigeria has a huge potential to increase the competitiveness of local rice through increasing yield growth, such growth alone is unlikely to be sufficient to completely displace imports in the short and medium term. The potential to grow is significant, nevertheless, and can be made more so through increasing the number of small-scale competitive rice farmers, encouraging small-scale and privately operated irrigation technologies, enabling fertilizer and other input markets to become more efficient, and promoting mechanization to encourage greater intensification.

Second, our analysis shows that import restrictions alone will not be effective at stimulating a large supply response. Model simulations suggest that production would increase by only about 20 percent even with very high tariffs. Even with reduced consumption because of higher rice prices, imports would still account for about 20 percent of total consumption. Thus, the simulations show that a policy of only raising import tariffs is not sufficient to significantly reduce rice imports. Consumers, especially the poor, who spend a larger share of their income on food, would be hurt most, from the increase in both rice prices and general food prices. At the same time, higher import tariffs would likely encourage further smuggling, underreporting, and rent-seeking activities. Alternatively, focusing more attention on technology change and market improvement offers a win–win strategy. With a modest increase in rice yields, together with the expansion of high-quality varieties to replace low-quality ones, our results show that competitiveness of local rice can increase. The competitiveness increases even more significantly when technology change is combined with improvements along the value chain after harvest. Both production and consumption increase while the import dependency ratio falls—benefiting both producers and consumers (urban and rural). At the same time, overall food prices do not rise as they do in the case of the high import tariff. If an import tariff is warranted, maintaining a consistent tariff policy together with committed public investment allocations to promote technology change and market improvements would be required to spur productivity growth. This is something that will not be easy to do considering the government's own record for implementing similar initiatives in the past.

Finally, results of our analysis of the rice postharvest sector conclude that the government should avoid picking winners in the large milling sector and instead encourage growth and technology upgrading among the smaller and medium-size firms. While meeting the demand for higher-quality premium rice in the short run is feasible only through the use of larger industrial mills as the government is already

[27] This section was authored by Michael Johnson and Kwabena Gyimah-Brempong.

promoting, there is a real danger that in years to come the sector would still have to rely heavily on government support to remain competitive. Experiences elsewhere in West Africa and Asia illustrate this pitfall. Meanwhile, by not paying sufficient attention to improving the small- to medium-scale sector, which we found to be more economically efficient, the demand for standard-quality rice would remain unmet. While this rice is less substitutable with imports, a majority of poorer consumers continue to rely on it relative to the more expensive premium brand (about half of total rice consumption). The potential to upgrade the small to medium milling sector exists, as our results show. The sector can easily absorb 25 percent in increased costs to further process and improve the quality of milled rice through de-stoning, polishing, and colorization, with an even greater return if the current high trader and marketing cost margins can be reduced. We also highlighted problems of access to electricity, credit, and storage, which can affect capacity performance and the ability to smooth out operations outside the typical harvest season.

It is unlikely that the small to medium sector can produce a quality premium brand comparable with products of the larger and more capital-intensive mills. However, it has the potential to produce rice of sufficient quality standards and at a low enough cost to be able to meet the demand and price preferences of the average consumer in Nigeria. If there is a key lesson from Asia and elsewhere in West Africa, it is that the growth and resilience of the small- to medium-scale millers has undoubtedly played a key role in contributing to the growth and transformation of rural economies. Over time, as incomes have risen and consumer preferences have shifted more toward higher-quality rice, the sector has been able to adapt and attract investors along its value chain in order to upgrade equipment and expand milling capacities. Government support has been critical, but mostly in providing access to the technologies and training; subsidizing credit and sometimes even the price of paddy; and investing in infrastructure to lower costs for energy, transportation, and access to markets and information. With these supports in place, subagents for paddy producers and other new trader entrants appear on the scene, including those specializing in postmilling operations such as de-stoning and colorization. Eventually, this route has led to the commodification of specific rice brands together with a system of quality grades and standards. While this process can take time, the Nigerian small to medium milling sector is poised to respond, given the right enabling environment.

Policy Implications and Discussion

Compared with its Asian counterparts, Nigeria not only faces the dual challenge of catching up to Asia's Green Revolution and transforming the rice postharvest sector, it also faces the additional task of reversing decades of neglect in agriculture. Doing so in a fashion that will lead to rice self-sufficiency in a short time makes it a potentially ominous challenge. Despite the enormity of the task, the government has laid out an ambitious path to achieve such a transformation through policy reforms and fiscal investments. Aside from import tariffs, the government is also introducing other policy reforms, institutional changes, and financing structures that include the deregulation of seed and fertilizer sectors, marketing reforms that involve promoting the setup of private market corporations that will help coordinate the market and set grades and standards, and innovative financing mechanisms for supplying credit. Additionally, interstate barriers to paddy trade, such as taxes, are also expected to be eliminated to reduce market transaction costs.

Among fiscal investments, a significant part involves establishing SCPZs that are intended to promote development of industrial clusters for food processing. Once established, the SCPZs will serve as agro-industrial clusters situated in areas with high production volumes of raw material in food staples (such as paddy for rice milling). This initiative also includes encouraging the expansion of paddy cultivation in close proximity to these clusters. The government promises to invest in basic infrastructure (roads, power, logistics, and storage) and tax-based incentives to encourage private investors in the food processing sector. Already, the government has begun the process of importing 100 large-scale integrated rice processing mills with a total expected capacity to produce 2 million tons per year (FMARD, 2012). Additionally, the World Bank and Africa Development Bank have since put aside some resources to help with setting up some of the SCPZs in 2013 (UNIDO 2012). According to the Federal Ministry of Agriculture and Rural Development (FMARD, 2011), there is an equally strong intention to provide support to the smaller-scale milling sector, including helping to set up rice milling associations to enable training and access to improved technologies and practices (such as equipment for packaging and branding, de-stoners, and color sorters), storage, and paddy variety selections for grading and maintaining milling quality standards. Additionally, establishing a guaranteed minimum price for paddy is also suggested. Although very good intentions, the extent to which these objectives are being implemented and achieved at the time of this writing was unclear.

The policy and investment framework proposed by Nigeria's ATA strategy is promising if it can be successfully implemented, and kept consistent and on course. Asia's own Green Revolution decades ago relied heavily on protective policies against imports and strong state involvement in providing subsidies and intervening in the market directly to help coordinate access to input and output markets and to stabilize prices (Johnson, Hazell, and Gulati 2003). In contrast, the Nigerian framework does not adopt such a heavy-handed state-led role but instead seeks to encourage private-sector investments, marketing, and credit financing arrangements—with the goal of achieving results within a very short time. It's worth noting that it took more than a decade for many countries in Asia to achieve their own Green Revolutions.

The ambitious design and implementation plan of the ATA for rice poses a number of policy challenges and risks. To begin with, a principal challenge for the government will be in implementing the policy and investment incentives needed in a short period (to 2015), maintaining the momentum and commitments into the future, and including the consideration of any careful sequencing required. As pointed out earlier, a key risk facing the government is whether its policy of high import tariffs would be politically feasible in the long run since it involves a major food staple. In the short run, it is more likely to encourage smuggling and underreporting while hurting poorer consumers the most.

Other risks, as our analysis has suggested, are those associated with focusing too much attention on expanding the capacity of large industrial milling. First, capitalization of milling through large industrial establishments alone could have the effect of undermining the core goals of the ATA itself for creating jobs and wealth in rural areas. This is because growth in the smaller milling sector is likely to have much higher multiplier effects given its labor-intensive activities and linkages across many more actors downstream and upstream in the domestic rice value chain. Second, the experience in Asia and elsewhere in West Africa makes it doubtful whether large-scale millers will be able to operate efficiently and profitably on their own indefinitely without relying heavily on government support. Finally, even if Nigeria could close current yield gaps in rice production, it will still fall short of meeting domestic demand in the short to medium term—including supplying sufficient paddy to the large milling sector. Moreover, the fiscal costs associated with subsidizing the large mills could rise to unmanageable levels over time—both from maintaining the subsidies and from ensuring paddy supply logistics.

Alternatively, simply focusing on reducing costs and improving access to technologies, knowledge, and markets in the small to medium milling sector may be sufficient to make local rice competitive in the long run. Setting up the so-called SCPZs offers an opportunity for improving this more-established sector. It has far more to gain from modest improvements in accessing storage, energy (for example, electrical power), water, roads, and transport. It has been shown to have the potential to significantly improve quality by simply upgrading existing equipment and undertaking further processing, given enough incentives. In fact, its flexibility to adapt has maintained its very existence through time in Nigeria, in the rest of West Africa, and in Asia. Focusing on existing clustered groups of millers would further benefit the agglomeration effects that they already enjoy, of having easier access to information, technologies, credit, and proximity to paddy growers. Within these clusters, the setup or strengthening of existing millers' associations as proposed in the ATA strategy is quite feasible. Through the associations, training and access to services for further processing (de-stoning, color sorting) and selection of paddy varieties for grading, packaging, and branding can be improved. The associations within these clusters can also become empowered to negotiate for better prices with middle traders, to insist on quality paddy varieties, and even to set up outgrower systems with other organized groups of farmers to assist with accessing seeds and other inputs, ultimately leading to lower input costs for both farmers and millers. An important principle here is that focusing attention on improving the performance of the dominant value chain through participation in the SCPZs will enable those who are most aware of the local dynamics of demand and supply to be able to evolve and respond according to their comparative advantage (Zhang and Whitney 2012).

Finally, to achieve the overall goal of displacing rice imports, it will not be enough to simply improve the competitiveness of domestic rice through quality and performance. Consumers may still prefer imported over domestic brands simply due to habit or lack of information (Akaeze 2010). Buyers will need to be aware of and become convinced of the value of domestic rice through quality branding and extensive marketing promotions—and this for both standard and premium-quality brands of local rice. One recent field experiment in Senegal by Demont and Rizzotto (2012) that assessed consumer behavior and preferences for local premium rice found that the problem was not about a lack of demand but more about improving the quality of branding and marketing. High-end Senegalese consumers were found to be quite willing to pay a quality premium for such improvements. Although less rigorous in approach, other studies in Nigeria have reached similar conclusions on the importance of branding and marketing (for example, Lodestar International 2010 and Akaeze 2010). In other words, improving the competitiveness of domestic rice through quality and price will not guarantee a market without promotional efforts to inform the consumer of the local brands.

APPENDIX A: SUPPLEMENTARY TABLES

Table A.1 Rice imports and exports by country of origin to Nigeria (various years)

Year	Importing country	Origin of imports	Total rice imports ('000 MT)	Total rice import value (US$million)	Total rice exports ('000 MT)	Total rice export value (US$million)	Reported imports as a share of exports to Nigeria
2006	Nigeria	India	317	118	612	157	51.8
2007	Nigeria	India	316	140	239	66	132.4
2008	Nigeria	India	51	32	66	21	77.9
2009	Nigeria	India	0	0	0	0	221.4
2010	Nigeria	India	1	2	0	0	274.2
2006	Nigeria	Thailand	1,705	126	367	109	465.2
2007	Nigeria	Thailand	72	40	334	110	21.6
2008	Nigeria	Thailand	15	10	846	624	1.8
2009	Nigeria	Thailand	43	3	1,038	577	4.2
2010	Nigeria	Thailand			1,330	639	
2009	Nigeria	Vietnam	3	4	3	1	82.2
2010	Nigeria	Vietnam	0	0	2	1	8.6
2006	Nigeria	World	2,552	424	1,028	280	248
2007	Nigeria	World	1,014	481	611	188	166
2008	Nigeria	World	160	96	1,021	708	16
2009	Nigeria	World	398	472	1,397	735	29
2010	Nigeria	World	711	495	2,053	818	35
2006	Nigeria	Other	530	179	50	14	1,069.2
2007	Nigeria	Other	626	302	38	12	1,642.9
2008	Nigeria	Other	94	54	109	64	86.5
2009	Nigeria	Other	352	465	355	156	99.1
2010	Nigeria	Other	710	493	721	178	98.4
2006	Benin	World	405	112	720	209	56.2
2007	Benin	World	682	211	948	302	71.9
2008	Benin	World	698	185	968	509	72.1
2009	Benin	World	683	91	897	466	76.1
2010	Benin	World	604	79	591	299	102.3

Source: Authors' calculations based on Comtrade data (UN 2012).
Note: MT = metric tons.

Table A.2 Rice marketing channels: Actors, roles and functions, and key constraints

Marketing channel	Actor	Roles and functions	Key constraints
Small and medium scale: This is the dominant channel, processing about 80% of paddy, and the millers are in the thousands across the country. • Paddy moves from traditional farmers and gets processed by hand mill for household consumption, with excess sold at the village market. • Paddy passes through paddy traders, parboilers, small and medium service mills, rice traders, and retailers, and ends at the rural town market, where consumers pick it up. • Paddies from traditional farmers (as contract farmers or outgrowers) and emerging commercial farmers get to the medium millers (who also grow, buy, and store paddy, and trade in milled rice), wholesalers, market retailers, and eventually to the final consumers.	Traditional farmers	Produce paddy at a small scale	Lack of inputs and improved varieties of seeds
	Contract farmers	Mostly from traditional farmers in contract farming	Inadequate capital for inputs
	Millers (farmers)	Perform hand milling of paddy	All processing stages are done manually
	Paddy traders	Buy paddy from the small-scale farmers	Inadequate capital for trading
	Parboilers	Parboil paddy for a fee for traders, millers, and consumers	-
	Small millers (may buy paddy too)	Mill parboiled rice for a fee for traders and themselves	-
	Medium millers (mostly buy paddy and trade too)	Grow their own paddy and also buy in the open market. This they parboil through artisans for a fee or sometimes themselves and then mill before they sell directly to institutionalized markets.	Inadequate supply of paddy, nonuniformity of paddy, and high cost of parboiling if contracted out, since few have mechanical parboilers
	Rice traders	Sell milled rice to wholesalers, retailers, and consumers in the market	-
	Wholesalers	Buy milled rice directly from millers and traders to resell to market retailers	-
	Rural retailers	Sell milled rice from traders to final consumers in rural towns	-
	Urban retailers	Get milled rice from rice traders and wholesalers to sell in the urban markets	
	Rural consumers	Farmers may consume their own product or buy at the village market; other rural dwellers rely on the village and small-town rural markets.	Milled rice contains foreign objects, stones, and so on
	Urban consumers	Consume milled rice from traders or retailers	Milled rice of low quality
Large industrial scale: This is a limited channel, processing less than 20% of total milled rice in Nigeria. • Paddy comes from the contract farmers / outgrowers who supply the integrated industrial processing mills. • The large mills also import brown rice, which they process along with the local paddy, and their milled rice is sold to wholesalers, market retailers, and then consumers.	Farmers	Mostly traditional farmers in contract with the big mill, but also large commercial farms owned by millers	-
	Industrial mills	Provide extension services and inputs to farmers (as credit in return for paddy after harvest), facilitate loans to farmers from commercial banks and also import brown rice for milling	Insufficient quality paddy
	Wholesalers	Buy virtually all the milled rice from the industrial millers	-
	Market retailers	Procure milled rice from wholesalers before selling in the market; also get a share of their milled rice from rice traders in the large scale channel	-
	Consumers	Mostly in the urban market (both low and high end)	-

Table A.2 Continued

Marketing channel	Actor	Roles and functions	Key constraints
• Increasingly, large milling firms are investing in growing their own paddy on large irrigated tracts of land to ensure a steady supply of paddy rather than relying on smallholder paddy growers.			
Importers:	Importers	Import milled and brown rice from abroad	Getting special license to import milled rice
• Multinational corporations import milled rice (packaged and bagged) from the United States and Asia, which they sell to the wholesalers, supermarkets, and shops. The wholesalers sell to the market retailers, who then push the product to consumers in the market.	Wholesalers	Buy milled or brown rice from importers, polish the brown rice and sell to market retailers	-
	Market retailers	Resell the milled product from wholesalers to consumers	-
	Supermarkets/shops	Sell milled rice from importers to consumers	-
	Consumers	Entirely in the high end of the urban market	-

Source: Based on field trip observations and DAI 2009.

Table A.3 List of agricultural sectors (products) included in economywide multimarket model

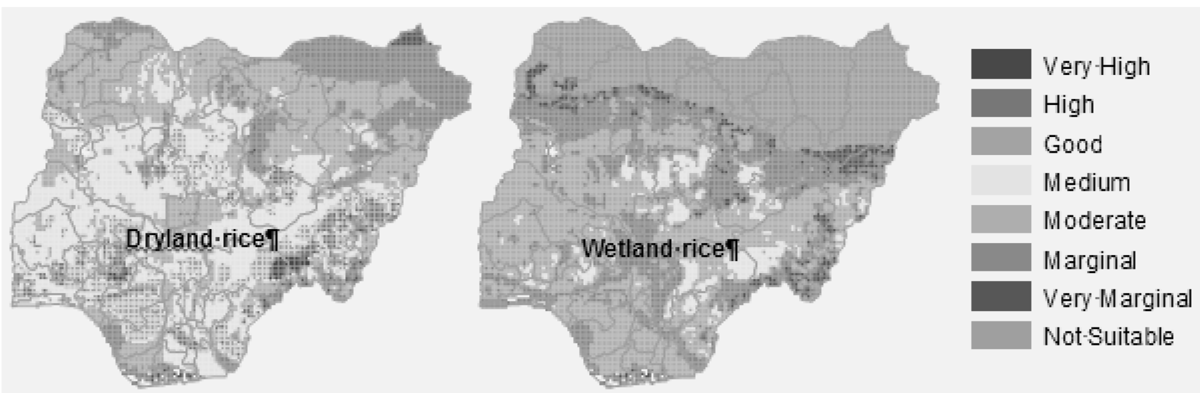
Crops		Livestock and fisheries
Cereals	**Cash crops**	**Livestock**
1. Maize	18. Cotton	27. Cattle
2. Rice	19. Sugar	28. Chickens
3. Millet	20. Cocoa	29. Sheep and goats
4. Sorghum	21. Coffee	30. Pigs
5. Wheat		31. Other livestock
6. Other cereals		
Root crops and tubers	**Fruits and vegetables**	**Animal products**
7. Cassava	22. Total vegetables	32. Beef
8. Yam	23. Total plantains	33. Poultry
9. Sweetpotato	24. Other fruits	34. Lamb and goat
10. Potato		35. Pork
11. Cocoyam		36. Other meat
		37. Milk
Oilseeds and pulses	**Tree nuts and spices**	38. Eggs
12. Groundnuts	25. Total spices	39. Skin
13. Soybeans	26. Nuts	
14. Oil palm		**Fisheries**
15. Sesame seed		40. Sea fish
16. Other oilseed		41. Fresh fish
17. Total pulses		

Source: Authors, from economywide multimarket model.

APPENDIX B: ESTIMATION METHODS FOR BIOPHYSICAL ANALYSIS

The Spatial Production Allocation Model (SPAM), Global Agro-ecological Zones (GAEZ), and Global Map of Irrigation Areas (GMIA) provide key information about the baseline and potential irrigation expansion scenario for the simulation. SPAM is an entropy-based method for estimating the production area and yield distributions for various crops on a global grid at a resolution of 1–10 km (You et al. 2011). The method uses subnational production data, satellite imagery of cropland, area equipped for irrigation, population density, crop prices, and the biophysical suitability of crop production in each grid cell (You and Wood 2006; You, Wood, and Wood-Sichra 2009; You et al. 2011). We used SPAM for assessing the distribution of current rice area (both rainfed and irrigated) and yield. GAEZ was developed by the FAO in collaboration with the International Institute for Applied Systems Analysis, Austria. Fischer, van Velthuizen, and Nachtergaele (2000) offered detailed descriptions of the model, from which we get the crop suitability data. GMIA was developed jointly by the FAO and the University of Frankfurt (2012) as a visual information tool on the areas that are equipped for irrigation around the globe.

Figure B.1—Rice suitability



Source: Global Agro-ecological Zones (GAEZ) software (v3.0) by Fischer et al. (2012).

Cropping System Model

A cropping system model (CSM) simulates the biophysical response of rice given the changed levels of inputs. Details of the CSM used in this study have been provided by Singh, Ritchie, and Godwin (1993) and Jones et al. (2003). We have used the CSM to integrate knowledge about soil, climate, crops, weather, genetics, soil water, soil carbon and nitrogen, and management, obtained from various diverse locations, to support transferring production technology from one location to others where soils and climate differed (Jones et al. 2003).

Using SPAM, GAEZ, GMIA, and CSM, the biophysical simulation proceeds in the following way:

1. From the SPAM model, we estimate the actual area under rice production.
2. For the area identified in step 1, we use GAEZ to estimate the area for different levels of rice suitability.
3. We estimate the potential for rice production increase by simulating various scenarios within the area currently under cultivation (identified in step 1), using the estimates from steps 1 and 2 as the base conditions.
4. From the simulation, we obtain for each grid square the baseline yield and potential yield under different scenarios.

Modification of Simulation Process

Various adjustments were used to align the simulation results with the reality on the ground and also to obtain conservative estimates of the yield impacts.

Scaling and Bias Correction

The CSM estimates both baseline and simulated yields of rice, where the former is based on the current use of nitrogen and water, and the latter are the yields simulated under different levels of nitrogen and water use. While the CSM captures some of the location-specific variations in key agroecological conditions when calculating the baseline yield, the actual yield can vary also due to other factors, including lack of knowledge on soils, irrigation use, sowing date, sowing density, fertilization, and pests (Boote 2012), which cannot be captured by CSM. A more realistic baseline yield can be estimated using SPAM. We then conduct the "bias correction" of the CSM yield by equating the CSM baseline yield with the SPAM yield, and correct all the simulated yields proportionately. A similar concept has been applied in other studies (Boote 2012).

Bias correction is done in the following way: First, we obtain simulated yields for both a traditional variety and an improved variety using baseline nitrogen application rates, as presented in Table 4.2 in the main body of the paper. We then calculate the baseline rainfed yield in each grid square, which is the average of yields for traditional and improved varieties, assuming each occupies 50 percent of area (Table 4.2 in main body of the paper). The baseline yields are then standardized to the SPAM yield in each grid square. All the simulation results are then scaled by the same bias correction factor. For example, if the baseline simulation yield in a particular grid square is 0.5 tons for the traditional variety and 1.7 tons for the improved variety, while the SPAM rainfed yield in that grid square is 1 ton, all the simulation results for that grid square are scaled down by 9.1 percent because the SPAM rainfed yield (1 ton) is 9.1 percent lower than the simulated baseline rainfed yield (= [0.5 + 1.7]/2 = 1.1 tons).

Dryland and Wetland Categorization in CSM

SPAM and CSM apply different categorizations of rice area. SPAM classifies area as rainfed or irrigated, while CSM distinguishes dryland and wetland. Therefore we match classifications of each model in the following way:

1. (simulated dryland rainfed yield) : (SPAM rainfed yield)
2. (simulated dryland irrigated yield) : (SPAM rainfed yield * *K*), where *K* is the yield impact from irrigation on dryland
3. (simulated wetland irrigated yield) : (SPAM irrigated yield)

Irrigated Area: Baseline

SPAM classifies both rainfed lowland rice and irrigated rice into "wetland rice," and we cannot distinguish the two. Because of this, SPAM assumes that almost one-third of the area under study is irrigated wetland rice. The actual area under a developed irrigation system in Nigeria, however, may be much lower, since the distinction of irrigated wetland and lowland wetland rice is often difficult to make. Therefore, we downscaled the "wetland rice" area in each grid square with the same proportion so that the total irrigated area becomes 10 percent of the total rice area. The share of 10 percent is chosen due to the lack of accurate information. For example, although Ezedinma (2008) suggested rice irrigation area to be 17 percent of the total rice area in Nigeria, the rice area under a fully developed irrigation system appears to be much smaller based on figures reported by the Enplan Group (2004). In order to stay conservative, we assumed that the actual share of irrigated rice area is 10 percent for the whole country, and we scaled down the irrigated area within each grid square proportionately to 30 percent of the original estimate (= 10/33).

In some grid squares, initially SPAM gives an irrigated yield only if it estimates that all the rice area in that square is irrigated. However, through the area share adjustment described above, part of such a grid square becomes rainfed. There is no SPAM rainfed yield for such a square. However, we have the simulated base yield for both dryland and irrigated (wetland) rice. Therefore, in this case, we estimated the SPAM rainfed yield such that

$$\frac{\text{SPAM rainfed yield}}{\text{SPAM irrigated yield}} = \frac{\text{dryland base yield}}{\text{irrigated (wetland) base yield}}. \qquad (1)$$

Irrigated Area: Expansion in Scenario 3

We simulated the expansion in irrigated area under scenario 3 in the following way, results of which are presented in Table 4.3 in the main body of the paper. We assumed that the short-term rice irrigation expansion is made possible by converting both areas where rainfed rice is currently produced and other areas that are currently under irrigation for other crops. For example, if the current irrigated rice area is 10, the current rainfed rice area is 20 based on SPAM, and the total irrigation area is 15 based on GMIA. Because SPAM does not distinguish irrigated from rainfed lowland rice, we make the conservative assumption that expansion of irrigated area from 10 to 15 may occur in the currently rainfed rice area that was initially classified by SPAM as irrigated (see discussion in the previous paragraph). Therefore, in this case, we expand the irrigated area from 10 to 15 while reducing the rainfed area from 20 to 15. If, on the other hand, GMIA estimates the irrigation area at 40 in this grid square, then we first convert the irrigated rice area from 10 to 30 while reducing rainfed rice area from 20 to 0, assuming the additional irrigated area purely comes from converting rainfed rice to irrigated. Then we further expand the irrigated area from 30 to 40, assuming the additional irrigated area purely comes from area currently devoted to other irrigated crops.

Baseline Yield and Rice Output

The baseline yield level as well as rice production are based on SPAM with some modification. The SPAM yield was originally adjusted to be consistent with the figures from the National Bureau of Statistics (NBS). Further, to remain conservative, we corrected the yield estimates from SPAM to the simulated base yield of biophysical potential, whenever the latter is lower than the SPAM estimate. This happened mostly for the rainfed area. Adjustment of irrigated area and correction of rainfed SPAM yield (discussed above) led to a more conservative estimate of the total output, compared with the NBS figure.

Last, simulated yield of irrigated rice with increased fertilizer application rates was calculated in two ways: (1) using the simulated impact and baseline yield of dryland rice and (2) using the simulated impact for irrigated rice. The simulated yield is generally higher for (2). We use (2) to calculate the yield for areas with high suitability, and we use the average of (1) and (2) for areas of medium and low suitability.

Other Components of the Simulation

Approximately 1 percent of grid squares did not report the baseline yield and are not included in the yield calculation—we masked out pixels with very low yield capacity (average simulated yield of less than 500 kg/ha). Some squares may also be close to a water body or country boundary and therefore present some data issues. Given the small share of such anomalies in the sample, the estimated yield effects are robust.

Example of Simulated Yield and Output Estimation

Examples in Table B.1 below describe how both rainfed and irrigated yields are calculated. The second column summarizes the initial condition, which is the SPAM yields and areas, as well as CSM results. Calculations for the third column are as follows:

1. Based on the SPAM rainfed yield and the CSM simulated yield, the factor for bias correction is 0.714 (= 500/[(400 + 1,000)/2]). Through bias correction, simulated dryland baseline yields for the traditional variety are changed from 400 to 286 kg/ha (= 400 * 0.714), and simulated dryland baseline yields for the improved variety are changed from 1,000 to 714. Similarly, the bias correction factor for irrigated area is 0.781 (= 2,500/3,200). Simulated wetland baseline yields is adjusted to 2,500, which is the same as the SPAM irrigated yield.
2. As was discussed above, irrigated rice area in each grid square is downscaled to 30 percent of the SPAM estimate. Therefore the adjusted areas in this square are changed from 100 to 114 for rainfed area, and 20 to 6 for irrigated area. Using the second column, the baseline output in this square is 72,000 (= [500 * 114] + [2,500 * 6]).
3. Simulated dryland yield in scenario 2 is 1,785 (= 2,500 * 0.714), and simulated dryland yield in scenario 3 is 2,857 (= 4,000 * 0.714). Similarly, simulated wetland yield in scenario 3 is 4,297 (= 5,500 * 0.781). Since square A is in an area of medium suitability, the irrigated yield in scenario 2 (which is also the same as the irrigated yield in scenario 3) is 3,577 (= [2,857 + 4,297]/2).
4. The rainfed and irrigated areas under scenario 3 change as follows:
    a. Irrigated area—all areas initially classified as irrigated under SPAM but reclassified as rainfed in step 2 are now converted back to irrigated area, so that the irrigated area becomes 20. The GMIA irrigated area in this grid square is 30, indicating that the remaining 10 is irrigated for other crops, which are also converted into rice irrigation in scenario 3. Therefore the irrigated area becomes 30 in this square.
    b. Rainfed area—14 (= 20 - 6) is converted from rainfed rice to irrigated rice. Therefore, the rainfed area is 100 (= 114 - 14).
5. Using the simulated yields and area changes throughout the above step, the outputs under each scenario in this grid square are the following;
    a. Scenario 1: 84,198 (= 114 * (286 * 0.25 + 714 * 0.75) + 6 * 2,500)
    b. Scenario 2: 182,231 (= 114 * (286 * 0.25 + 1,785 * 0.75) + 6 * 3,577)
    c. Scenario 3: 248,335 (= 100 * (286 * 0.25 + 1,785 * 0.75) + 30 * 3,577)

Table B.1 Example of baseline, simulated yield, and output estimation

Grid square A (medium suitability)	Initial condition	Adjusted base	Calculated yield	Area in scenario 3
SPAM rainfed yield	500			
SPAM irrigated yield	2,500			
Simulated yield				
Traditional base—dryland	400	286	286	
Improved base—dryland	1,000	714		
Improved—fertilizer—dryland (scenario 2)	2,500		1,785	
Improved—fertilizer/irrigated—dryland (scenario 3)	4,000		2,857	
Improved base—wetland	3,200	2,500		
Improved—fertilizer—wetland (scenario 2)	5,500		4,297	
SPAM rainfed area	100			
SPAM irrigated area	20			
GMIA irrigated area	30			
Simulated rainfed area		114		100
Simulated irrigated area		6		30

Source: Authors.

APPENDIX C: CLUSTER ANALYSIS

Cluster analysis methods are often used to classify agents into various types (Anderberg 1973), relying on dissimilarities between the observations based on their numerical values. Following the descriptions by Hansen and Jaumard (1997), our cluster analysis proceeds in the following steps: First we select a sample $O = \{O_1, O_2, ..., O_N\}$ of N observations. We then measure p characteristics of the sample, yielding $N \times p$ data matrix X. From the matrix X, we compute an $N \times N$ matrix $D = (d_{k\ell})$ of dissimilarities between samples, where $d_{k\ell}$ usually satisfies

$$d_{k\ell} \geq 0, d_{kk} = 0, d_{k\ell} = d_{\ell k} \text{ for } k, \ell = 1, 2, ..., N. \quad (2)$$

We then apply cluster analysis to dissimilarity matrix D, by selecting (1) the types of clustering (partitioning and constructing a hierarchy of partitions) and (2) criteria to express homogeneity, separation, or both, of the clusters, and particular algorithms. Hierarchical partitions and *k*-means partitions are two of the commonly used partitioning methods. Agglomerative hierarchical clustering algorithms are one of the most used hierarchical methods, in which we start from *N* clusters consisting of each observation and gradually agglomerate multiple observations that are similar to each other until the number of clusters decreases to the desired level. In *k*-means clustering, mean values of each variable are set arbitrarily for each of set number of clusters, and observations are assigned into each cluster depending on their distance to the mean values. For (1) we combine the hierarchical partitions with *k*-means partitions, a method proposed by Punj and Stewart (1983) and by Siou et al. (2011), because combining two partition methods can significantly improve the accuracy of clustering. For (2) we follow Punj and Stewart (1983) and Siou et al. (2011), where the standard deviations of variables *p* are minimized within the cluster, while the standard deviations of cluster-mean of *p* are maximized across clusters. Although cluster analysis provides statistical criteria, and the methodology by Punj and Stewart (1983) and Siou et al. (2011) tends to suggest that the more clusters the better, we limit the maximum number of clusters to be generated, since the interpretation becomes difficult if there are too many types of households. Using hierarchical partitions is useful in that sense, since the samples tend to be clustered in hierarchical structure, and increasing the number of clusters may not affect most of the other clusters that are already identified.

We use *Nigeria's Living Standard Measurement Survey–Integrated Survey on Agriculture* (LSMS-ISA) 2010 data (Nigeria, NBS; and World Bank 2011), supplemented with various secondary data. The LSMS-ISA data were collected jointly by Nigeria's National Bureau of Statistics and the World Bank. The data cover all of Nigeria and well represent all types of farm households, and are thus appropriate for analyzing the typology of major farm households in Nigeria. The LSMS-ISA data consist of a postplanting survey, covering January 2010 through August 2010, and a postharvest survey, covering September 2010 through March 2011.

Table C.1 summarizes the variables used for the cluster analysis, which are selected in order to capture the comprehensive characteristics of farm households in terms of production behaviors and resource constraints. Variables are selected following similar past studies (Simler 1994; Dorward 2006) to capture the various aspects of rural farm households, including agroecological environment, size of cultivated area (both rainfed and irrigated), inputs use (total expenditure on fertilizer and agrochemicals), production technology (irrigation and mechanization), hiring of harvesting labor, wealth status (household assets and expenditure on nonfood consumption goods, plus other sources of income), and nonfarm income-earning activities.

Agroecological and market access variables are all calculated as the average at local government area (LGA) level within each of the 37 states in Nigeria, except the farming system and soil types, for which the dominant classes are assigned to each LGA. Two farming system zones are distinguished, following Dixon et al. (2001): (1) northern farming system, consisting of (1a) cereal–root crop mixed system, (1b) agropastoral/millet/sorghum system, and (1c) pastoral system; and (2) southern farming system, consisting of (2a) root crop system, (2b) tree crop system, and (2c) coastal artisanal system. Each LGA is assigned into a northern or southern system, whichever covers the majority of the area. Soil types are classified based on FAO/IIASA/ISRIC/ISSCAS/JRC (2009) into alluvial soil (consisting of Fluvisols, Gleysols, and Vertisols) and other types, since a large portion of alluvial soils are regarded as more fertile than other types of soil in Nigeria (Agboola 1979) and therefore different farming systems may be applied. Historical rainfall variation is based on data from the University of East Anglia (2012). Distance to the major rivers is calculated using data from FAO (2000). Population density and distance to towns of 20,000 and 50,000 inhabitants are each constructed using data obtained from the HarvestChoice Project (2012).

Table C.1 Variables used in cluster analysis

Category	Variables
Agroecological (natural resources)	Farming system zones—north and south Soil type (dominant types in each LGA) Historical rainfall variation (LGA average) Distance to major rivers (LGA average) Distance to the nearest dams (LGA average)
Market access	Total population density in the region where the household is located Distance to towns of 20,000 or 50,000 inhabitants
Resources (human resources)	Household size Literacy of household head Gender of household head
Resources (assets)	Total value of assets, not including land Size of livestock-equivalent stock or value of animal stock owned
Labor resources	Real LGA median wage for land clearing/preparation (– ratio to LGA rice price)
Land tenure	Whether owns any of the rice plots
Production scale	Total rainfed area
Production scale under irrigation	Whether used irrigation or not Whether used irrigation based on diverted stream or not
Production intensity	Overall input intensity measured as the total value of inputs per ha of rice area: • Fertilizer expenditure on rice-grown plot • Whether purchased seed or not for the most recent production season • Pesticide, herbicide expenditure on rice-grown plot Animal traction (number of days per ha) used on rice plot Whether used tractor or not on rice plot Tractor (number of tractors used per ha of rice plot) used on rice plot Whether hired labor for harvesting rice Whether sold / gave out as gift any of the harvest Whether took out any loan/credit (including nonagricultural credit) from either formal or informal sources
Income, nonfarm activities	Total expenditure on nonfood items per person Salary/wage income in off-farm activities last month Net nonfarm business income last month Remittance income last month, other types of income (savings interest, rental of property, and so on)

Source: Authors
Note: LGA = local government area.

The real agricultural wage variable is the LGA median daily wage for an adult male for land clearing/preparation, standardized by the LGA median maize price, both obtained from the community surveys conducted in sampled LGAs as part of LSMS-ISA data (Nigeria, NBS; and World Bank 2011). Maize price is used because maize is almost universally grown and sold across Nigeria. Though the wages were asked for both rural and urban sectors, for different crops, and for different types of workers (gender, adulthood), no substantial variations were observed across those categories. Wages for an adult male are therefore representative. Large variations in real wages are observed across the regions.[28]

Other variables were constructed from the LSMS-ISA data (Nigeria, NBS; and World Bank 2011) to measure the human and land resources, assets, production scale (both rainfed and irrigated), production intensity, sales orientation, income, and nonfarm activities. These variables include household size; gender of household head; whether the head is literate and received formal education or not; per capita value of assets (household assets, not including land and livestock); annual per capita household expenditure on nonfood items; amount of other types of income, such as savings interest, rental of property; total area cultivated (each of rainfed and irrigated); cost of fertilizer, seed, and chemicals per ha; total number of days of animal traction use; total number of tractors used; and whether the household owned any of the farm plots cultivated, used irrigation, used animal traction, used tractors, hired harvesting labor, took out any loan or credit including nonagricultural credit from either formal or informal sources, sold harvest, or earned any income from nonfarm activities one month before the interview.

[28] Some communities responded by citing wages for multiple crops. Due to the paucity of the sample, each response is treated independently when calculating the median wage. For example, if one community gave a response for each of two crops while another gave only one response, the median is calculated from the total of three responses. The data do not provide the specific season in which the wage was measured. Though large variations were observed for wages within some states, they are unlikely to be due to seasonality, since the community survey was conducted during the postplanting period, typically from August to October, for all locations. In addition, variations in wages appear to be spatially correlated within each region. Therefore, we believe the variations within each state, which are substantial, represent reliable data and not misreporting.

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