INTERNATIONAL
FOOD POLICY
RESEARCH
INSTITUTE

IFPRI

IFPRI Discussion Paper 01493

December 2015

Optimal Tariffs with Smuggling

A Spatial Analysis of Nigerian Rice Policy Options

Michael Johnson

Paul Dorosh

Development Strategy and Governance Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The International Food Policy Research Institute (IFPRI), established in 1975, provides evidence-based policy solutions to sustainably end hunger and malnutrition and reduce poverty. The Institute conducts research, communicates results, optimizes partnerships, and builds capacity to ensure sustainable food production, promote healthy food systems, improve markets and trade, transform agriculture, build resilience, and strengthen institutions and governance. Gender is considered in all of the Institute's work. IFPRI collaborates with partners around the world, including development implementers, public institutions, the private sector, and farmers' organizations, to ensure that local, national, regional, and global food policies are based on evidence. IFPRI is a member of the CGIAR Consortium.

AUTHORS

Michael Johnson (m.johnson@cgiar.org) is a senior research fellow in the Development Strategy and Governance Division of the International Food Policy Research Institute (IFPRI), Washington, DC.

Paul Dorosh is division director of the Development Strategy and Governance Division of IFPRI, Washington DC.

Notices

[1.] IFPRI Discussion Papers contain preliminary material and research results and are circulated in order to stimulate discussion and critical comment. They have not been subject to a formal external review via IFPRI's Publications Review Committee. Any opinions stated herein are those of the author(s) and are not necessarily representative of or endorsed by the International Food Policy Research Institute.

[2.] The boundaries and names shown and the designations used on the map(s) herein do not imply official endorsement or acceptance by the International Food Policy Research Institute (IFPRI) or its partners and contributors.

Contents

Tables

Figures

ABSTRACT

Utilizing a spatial multimarket model for rice in Nigeria that explicitly takes into account the potential for smuggling, this paper analyzes the welfare implications of alternative rice tariff rates given the government's goals of spurring domestic production and reducing imports. Because smuggling occurs through the diversion of imports from Lagos, the official port of entry in the south, to the north, our modeling framework also captures the spatial effects of higher tariffs on changes in rural and urban prices, production and consumption, the flow of trade in rice, and welfare across different parts of the country. Results show that tariff rates that exceed about 40 percent introduce some smuggling of rice through the north because smuggling has become more profitable than importing through official channels in the south. It is also at this tipping point that government tariff revenues are maximized. At higher tariff rates with smuggling, the south experiences greater welfare losses, especially in urban areas.

Keywords: optimal tariff, smuggling, spatial market equilibrium model, rice, Nigeria

ACKNOWLEDGMENTS

We wish to thank two anonymous reviewers of a previous version of this paper and various participants at a policy seminar sponsored by the Nigeria Strategy Support Program in Abuja in September 2014, which motivated the study. The study would not have been possible without relying heavily on the results of research conducted during the preparation of *Transforming the Nigerian Rice Economy*, often cited in this paper, and input from contributing authors for the book. Finally, we wish to thank the Abuja office of the United States Agency for International Development for financing the study through its support to the Nigeria Strategy Support Program (NSSP). This paper is also published as NSSP Working Paper 29.

1. INTRODUCTION

As in many West African countries, rice consumption and imports in Nigeria have grown very rapidly in the last few decades. Rice is now a leading food staple in Nigeria, accounting for 11.2 percent of calories consumed and 6.6 percent of household food expenditures (FAO 2014; Gyimah-Brempong and Kuku, forthcoming). Although production has increased rapidly in recent years, longer-term growth rates are low and rice imports have surged from an average of 590,000 tons1 per year in the 1990s to 2.42 million tons in the period 2010 to 2012 (Table 1.1).

Table 1.1 Nigeria average annual rice imports, production, and domestic availability, 1960–2012

Period	Rice imports (thousand mt)	Rice production (thousand mt)	Rice domestic availability (thousand mt)	Share of imports in availability (percent)
1960–1969	1	222	201	0.5
1970–1979	199	357	520	38.3
1980–1989	529	866	1,308	40.4
1990–1999	590	1,818	2,226	26.5
2000–2004	1,679	1,851	3,346	50.2
2005–2009	1,790	2,131	3,653	49.0
2010–2012	2,417	2,725	4,869	49.6

Source: US Department of Agriculture data (USDA, 2013).
Notes: All quantities are milled rice.

This large increase in imports has not gone unnoticed by the Nigerian government, which considers it a major policy concern. In particular, rice features prominently in the government's agricultural development strategy, the Agricultural Transformation Agenda (ATA), launched in 2012. Aside from increasing public investments in the sector to raise productivity as well as volume and quality of output, the ATA strategy included the introduction of higher rice import tariffs in order to slow the growth in rice imports. Thus, the government increased the import tariff on rice from 50 percent to 110 percent in January 2013. However, customs data, price movements, and anecdotal evidence from field observations by the authors suggest that the increase in the rice tariff led to the diversion of the bulk of rice imports from official channels to informal ones, either through customs evasion at the main port in Lagos or through smuggling from neighboring countries, especially Benin and Niger.

In this paper, utilizing a spatial multimarket model for rice in Nigeria that explicitly takes into account the potential for smuggling, we analyze the welfare implications of alternative rice tariff rates given the Nigerian government's goals of spurring domestic production and reducing imports of rice. Our modeling framework also captures the effects of alternative tariff levels on rural and urban prices, production, consumption, economic surplus, and government revenues. Section 2 of this paper presents a brief overview of Nigeria's rice economy, with a focus on trade policy and imports. Section 3 describes the simulation model, data, and parameter values. Simulation results of the impacts of a range of import tariffs under alternative assumptions of the extent of smuggling are given in Section 4. Section 5 reviews results from sensitivity analyses of key model assumptions and parameters. We discuss policy implications and conclusions in Section 6.

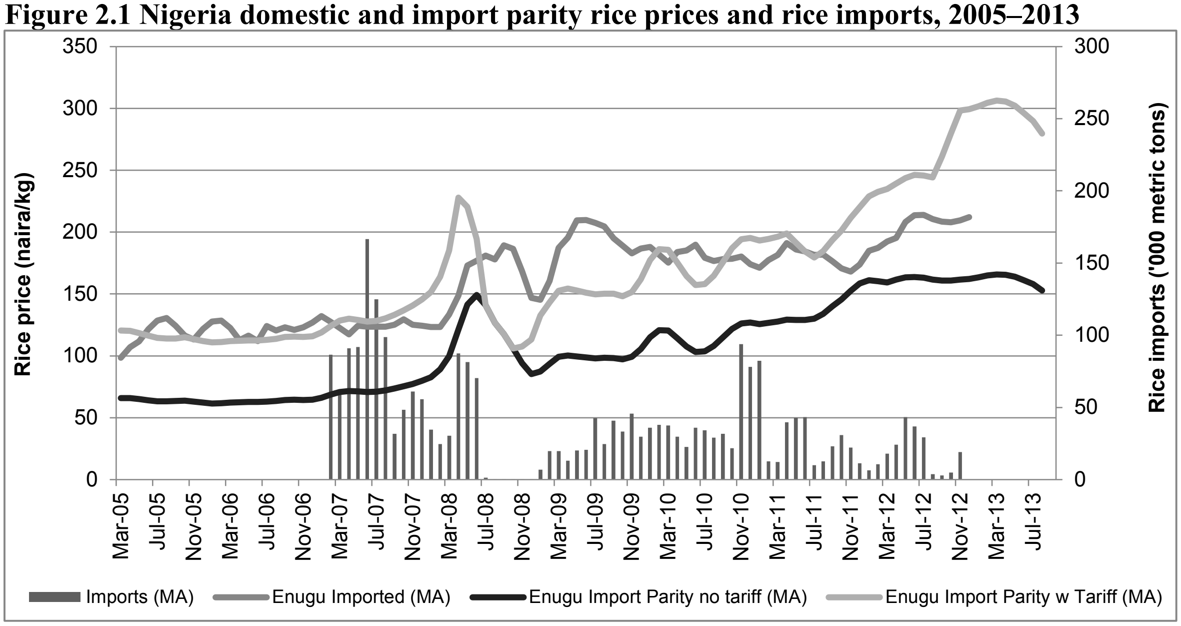
[1] Throughout the paper, tons refers to metric tons.

2. NIGERIA'S RICE ECONOMY AND RECENT TRADE POLICY

Rice production in Nigeria has increased substantially since the 1960s, but rice still accounts for a relatively small share of area cultivated, as wide variations in rainfall, soil characteristics, and water availability, as well as farmers' risk reduction strategies, all contribute to the widespread cultivation of cassava, yams, maize, sorghum, and millet across Nigeria (Takeshima and Bakare, forthcoming). Related to this diversified production pattern, the composition of staple food production also varies across Nigeria, with sorghum and millet consumed widely in northern Nigeria, and maize and root crops dominating consumption patterns in the south and middle zones. Overall, five crops each account for about 10 percent of national calorie consumption: rice (11.2 percent), yams (10.1 percent), cassava (10.1 percent), maize (9.9 percent), and sorghum (9.3 percent). Wheat, with very little domestic production, accounts for 6.6 percent of total calorie consumption (FAO 2014).

Rice cultivation is concentrated mainly in Nigeria's middle belt in areas where seasonal flooding or water from streams and rivers provides sufficient water. Low yields, high production costs, and lack of sufficient modern milling technologies contribute to the comparative disadvantage of domestic rice production relative to imports. Recent work by Johnson (forthcoming) estimates overall production costs along the rice value chain as twice those found in Thailand, for example. Rice milling is dominated by small-scale millers who produce varying qualities of standard milled rice, often with significant impurities (Johnson, forthcoming). As a result, consumers typically prefer premium rice varieties that either are imported or are produced locally by a few large-scale millers. Nevertheless, government efforts to boost rice production have met with considerable success in recent years, as evidenced by a 4.2 percent average growth rate from 2005 to 2012 (Figure 2.1). However, growth in demand for rice has outpaced production increases.[2]

Figure 2.1 Nigeria domestic and import parity rice prices and rice imports, 2005–2013



Source: Dorosh and Malek (forthcoming) using Nigerian Bureau of Statistics import data.
Notes: MA = moving average. Data are three-month lagged moving averages. Monthly import data are unavailable for 2005, 2006, and 2013. The choice of Enugu here was to illustrate a domestic market not at the port of entry for rice imports. "Enugu imported (MA)" is the observed domestic market price of imported rice in Enugu, while "Enugu import parity w tariff (MA)" and "Enugu import parity no tariff (MA)" are, respectively, the cost of imported rice in Enugu with and without tariff.

[2] Note that there is substantial uncertainty regarding agricultural production data in Nigeria, and figures vary considerably by data source.

Data from the Food and Agriculture Organization (FAO) on annual rice imports into Nigeria suggest that they have increased by approximately 1 million tons per year in each decade since 1970 (FAO 2014). Data on rice imports into Nigeria are especially uncertain, however. Official customs data indicate that rice imports averaged 384,000 tons per year from 2009 through 2011. The UN Comtrade database (UN Statistics Division, 2012) on total exports of rice to Nigeria for these years indicate that Nigeria's imports were five times larger (1.916 million tons). Customs data on tariff payments are broadly consistent with the official tariff rate schedules—that is, it appears that most imports that are recorded by customs are charged the official tariff rates.

Nigeria has adjusted its rice tariff rate numerous times in recent years. From 2005 to mid-2007, a 100 percent tariff was imposed on rice imports. During this period, import parity prices that include the import tariff and any other costs of importing to the local market were broadly stable (Figure 2.1). International rice prices rose sharply in 2007 and 2008, as did wheat and maize prices, especially following restrictions on rice exports by India and Vietnam that reduced supplies on the global market. In order to prevent a large increase in domestic prices of rice, Nigeria reduced its rice import tariff to zero in April 2008.

The rice import parity price dropped below N 130 (Nigerian naira) per kilogram by June 2008, while domestic prices remained high. Imports thus appear to have been constrained during the period from mid-2008 through late 2009, a time when there were no official trade restrictions. The large gap between import parity prices and domestic prices suggests that substantial excess profits (rents) were being obtained in this period. By early 2010, import parity prices at Enugu had risen and were again approximately equal to the domestic price through the end of 2011. Import tariff rates from 2009 through 2011 averaged 60 percent, but estimated average tariffs collected, adjusting for the gap between the official Nigerian and the Comtrade data on rice exports to Nigeria, averaged only 12 percent of import value (Table 2.1).

Thus, data on rice prices and tariff collection suggest that rice import tariffs are not effectively enforced and have only a muted effect on prices, at best. Nonetheless, these tariff policies may have significant effects on incentives for rice millers and large importers, some of whom may pay tariffs or face other costs associated with rents arising from tariff evasion. In this case, the rice trade policy may actually play a significant role in promoting industrialization using the "infant industry" argument.3 The practical challenge for Nigerian policymakers, however, is selecting an optimal tariff rate for rice that can still benefit society overall even when faced with the threat of smuggling. This means selecting a tariff rate that is not only effective at helping to reduce some imports while promoting local production, but can minimize any resulting net social welfare losses from rising prices and public-sector costs associated with managing the tariff—for example, lost revenues from tariff evasion or costs associated with smuggling prevention. Additionally, producer and consumer welfare is likely to vary widely across Nigeria given varying supply and demand dynamics, including those between urban and rural areas, as a result of rising tariffs on import flows through both official and nonofficial channels. The objective of this paper is to analyze whether such an optimal rice import tariff exists for Nigeria, especially given the potential for smuggling and the varied welfare implications for consumers and producers across different locations.

[3] The role of trade policy in development has long been debated, particularly whether trade liberalization or import-restrictive policies are effective for promoting industrialization and growth (Krueger 1997). Many have argued that trade liberalization may not be the best policy due to uncertainty in global prices (Jabara and Thompson 1982) or domestic capital and labor market failures, as in the "infant industry" argument (Krueger 1997).

Table 2.1 Nigeria rice imports, tariffs, and market prices for imported rice, 2008–2013

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Year	Cost and freight (C&F) Lagos, $/mt	Implicit *ad valorem* tariff rate, %	Official/ total imports, %	Average effective tariff rate on total rice imports, %	Parity price (no tariff), naira/kg	Parity price (w/tariff) at Enugu, naira/kg	Actual price at Enugu, naira/kg	Nominal rate of protection (NRP), (7)/(5) – 1	% difference between actual and parity price at Engug (w/tariff) (7)/(6) – 1
2008	550.2	44	18	8	112.9	156.6	161.6	43	3
2009	373.4	64	17	11	100.5	183.8	194.7	94	6
2010	430.0	64	28	18	116.4	126.1	179.4	54	42
2011	508.2	52	12	6	138.9	182.0	179.1	29	-2
2012	583.9	72	10	8	162.1	261.6	206.7	28	-21
2013	577.5	110	--	--	162.1	298.4	--	--	--
Avg. 2009–2011	437.2	60	19	12	118.6	164.0	184.4	55	12
Jan–Aug 2012	581.8	58	--	--	161.3	241.2	204.3	27	-15
Sept–Dec 2012	588.1	100	--	--	163.6	302.4	211.5	29	-30

Source: Authors' calculations based on Nigerian Bureau of Statistics (Nigeria, NBS 2012) and Comtrade data (UN Statistics Division, 2012).

Notes: The figures indicate a very low rate of official tariff collection. However, the high prices in retail markets suggest that substantial rents were obtained, possibly including unofficial payments. (1) C&F Lagos is calculated as 5 percent Thai broken rice plus $44.28/mt freight costs (data files, Anderson 2009). (2) The implicit *ad valorem* tariff is based on monthly data of import tariffs collected and declared customs values (2008–2011) and on official tariff rates (2012–2013). (3) Calculated from NBS and Comtrade data (UN Statistics Division, 2012). (4) Average rate of tariffs is the estimated total revenues (implicit average tariff x official imports) / total (USDA, 2013, est.) rice imports. (5) Parity price with no tariff at Enugu is calculated as [C&F Lagos + port handling charges, and transport and marketing costs to Enugu] x (1 + 50 percent retail margin). (6) Parity price w/tariff at Enugu is calculated as [C&F Lagos + tariffs + port handling charges, and transport and marketing costs to Enugu] x (1 + 50 percent retail margin). (7) Actual price at Enugu from the Nigerian Bureau of Statistics (Nigeria, NBS 2012). (8) The NRP Enugu imported price is calculated as [(actual retail price / imported parity price with no tariff) – 1]. (9) The percent difference between the actual retail price (7) and the imported parity price w/tariff (6).

3. THE SPATIAL MULTIMARKET RICE MODEL AND DATA SOURCES

In this paper, we use a spatial equilibrium model in the tradition of Takayama and Judge (1964), Harker (1986), and others. These models were originally cast as simple transportation problems and solved using linear programming optimization routines involving minimization of transportation costs between regions, given prices and excess supply and demand, or maximizing social welfare (net producer and consumer surplus) subject to transportation costs and the usual demand and supply constraints.[4]

A number of situations have been shown to be more ideal for using complementarity programming: for example, when considering *ad valorem* taxes (for example, on transport), tariffs on trade with the rest of the world, and other quantitative restrictions, as noted by Arndt and Schiller (2000). For *ad valorem* taxes, Rutherford (1995) argued, for example, that the resulting solution using a nonlinear programming approach can be quite inefficient because it would require solving a sequence of nonlinear programs. The complementarity formulation, on the other hand, is straightforward and more transparent. For investment models, Takayama and Hashimbo (1984) also pointed out that linear complementarity programming models have a more direct mechanism to solve for regional market demand quantities that are consistent with market prices, or to use when supplies are fixed. Overall, the authors noted, such models tend to respond more smoothly to continuous parameter shocks.

A key advantage of using the complementarity programming approach for our purposes is that it allows easy application of and direct economic interpretations based on Karush-Kuhn-Tucker (KKT) conditions. At the same time, the process has the added advantage of transparency in arriving at an optimum solution when considering price-responsive supply and demand equations (Rutherford 1995), as we do in this study.

Mathematically, a generalized form of the spatial equilibrium problem is typically solved as a nonlinear optimization problem that maximizes net social welfare subject to transportation costs, a world price for imports, and local supply and demand constraints. Net social welfare benefits are measured as the integrals of the inverse demand and supply functions.[5] By taking the first-order conditions and using the KKT conditions for a local maximum, the problem can be converted into its complementarity expression as a system of relational inequalities and complementarity variables.

Using this general specification of the complementarity problem, we develop a two-commodity spatial equilibrium rice model for Nigeria to simulate two distinctive rice commodities in all of its 47 states and in two types of markets, rural and urban. The commodities are a standard and a premium rice variety. The standard variety is of poorer quality, produced locally, and marketed as loose grain. The premium variety represents either an imported variety from world markets or a locally produced variety processed by large-scale millers. The locally produced premium rice is of a much higher quality than standard rice and is packaged and marketed as a branded product. The two varieties are imperfect substitutes, with the standard variety more popularly consumed by poorer households and in rural areas due to its lower price.

Trade between regions occurs when the price difference between them reaches the full cost of transporting goods between the regions. Similarly, commodities are imported when the wholesale price in a region rises as high as the import parity price for that region; they are exported when the price falls as low as the region's export parity price. Because Nigeria is an importer that accounts for only 7 percent of world rice imports, we assume it is a "small country" and cannot influence the world price. In other words, the world rice price is considered an exogenous variable in the model. Imports are allowed to enter two ports, in two different states. The first is Lagos in the south, which is considered the principal port for which an effective import tariff can be successfully introduced. The second is Kano in the north, for which unofficial imports can enter via the free port of Cotonou in the neighboring country of Benin.

[4] As Rutherford (1995) would show later, the simple linear programming problem could be translated into a complementarity one. This was desirable under certain conditions when the use of linear or nonlinear programming approaches proved less efficient.

[5] This is really the net of consumer and producer surplus.

Assuming quadratic demand and supply functions (Q_{kj}^{d}) in region j and (Q_{ki}^{s}) in region i for commodity k ($k = 1{,}2$), and allowing for some limited cross-price effects, these and their complementarity variables are represented in the model as[6]

$$Q_{kj}^{d}(P_{kj}) = \alpha_{kj} - \sum_{l} \beta_{lj} P_{lj} \,, \perp Q_{kj}^{d} \geq 0 \;\forall i,j \in N, \forall k, l = 1{,}2 \tag{1}$$

and

$$Q_{ki}^{s}(P_{ki}) = \gamma_{ki} + \sum_{l} \delta_{li} P_{li} \,, \perp Q_{ki}^{s} \geq 0 \;\forall i,j \in N, \forall k, l = 1{,}2, \tag{2}$$

where l is an alias of commodity k (that is, $l = 1{,}2$) to allow for cross-price effects, α_{kj} and γ_{ki} are intercepts, and β_{kj} and δ_{ki} are slope parameters for demand and supply curves, respectively, of commodity k ($k = 1{,}2$), with $\beta_{kj} < 0$ and $\delta_{ki} > 0$. Equilibrium conditions for excess supply and demand determine the equilibrium prices of each commodity within each region, as follows:[7]

$$Q_{ki}^{d}\big|_{\,k=1} = Q_{ki}^{s} + \sum_{i=1}^{N} \sum_{j=1}^{N} (X_{kji} - X_{kij}) \,, \perp P_{kj} \geq 0, \forall ij \in N, \forall k = 1 \tag{3}$$

and

$$Q_{ki}^{d}\big|_{\,k=2} = Q_{ki}^{s} + M_{ki} + \sum_{i=1}^{N} \sum_{j=1}^{N} (X_{kji} - X_{kij}) \,, \perp P_{ki} \geq 0, \forall ij \in N, \forall k = 2\,. \tag{4}$$

As before, the variable X_{kij} represents trade flows between regions for each commodity—that is, the quantities of commodity k that are transported between a supply region i and a demand region j. These are constrained as positive; that is, commodity k can be transported in only one direction at each given time. M_{ki} represents imports of the premium commodity ($k = 2$). X_{kij} and M_{ki} are determined separately by the price relationships in equations (5) and (6) below, respectively.

As market equilibrium conditions, equations (3) and (4) express the requirement that supply quantities of commodity 1 and 2 shipped between regions have to equal the quantities demanded in the region receiving them. Similarly, the quantity shipped out by a region cannot be more than what is available in the region to ship, less any quantities demanded locally. Both equations determine the equilibrium prices for each commodity type, P_{1j} and P_{2i}, respectively.

Now, given transportation and marketing costs, c_{ij} (again using the same notation as in the general case for either commodity), we can now determine the trade flow (X_{kij}) between regions. As the complementarity variable here, it is determined by the price differential between regions, inclusive of transportation and marketing costs (c_{ij}):

$$P_{ki} + c_{ij} = P_{kj}, \perp X_{kij} \geq 0. \tag{5}$$

Furthermore, since we have added the option for importing commodity 2, premium rice, from world markets, and we wish to add an import tariff (τ_i), plus an optional transportation or freight cost (α_i) for any imports diverted to another port to evade the tariff, we can express this price relationship as follows:[8]

---

[6] An additional subscript not shown here is the disaggregation of regions *i* and *j* by rural and urban. This was purposefully left out simply to avoid complicating the presentation. These can be treated the same way as the regions—except now with higher-matrix dimensions of the regions because trade can also occur between rural and urban areas across states.

[7] This is really combining equations (1) and (2) from the more general specification of the spatial equilibrium model.

[8] An unconventional aspect here is the option to import through nonofficial channels to avoid the import tariff (τ_i), but with an added freight cost (α_i) to divert the imports.

$$\bar{p}_{2i^{a,b}}^{w}(1+\tau_{i^a})+\alpha_{i^b} \;\geq\; P_{2i^{a,b}}, \perp M_{2i} \geq 0 \; i^a = Lagos, i^b = Kano. \tag{6}$$

Here, $\bar{p}_{2i^{a,b}}^{w}$ is the world price at either of the two ports for world imports (a = Lagos; b = Kano), including any port handling charges and fees. This is prior to adding the cost of the tariff (at Lagos) and freight costs to evade the tariff (at Kano). For Kano, in the northern part of Nigeria, imports are assumed to initially enter through the free port of Cotonou in Benin and then to be transported overland through Benin and Niger before entering Nigeria at Kano. Equation (6), therefore, is specifically designed to determine the optimal volume of imports from world markets and at which port, depending on the final price differential between the two ports given the values of τ_i and α_i. Simply put, if $\bar{p}_{2i^a}^{w}(1+\tau_{i^a}) + c_{i^a j} \geq \bar{p}_{2i^b}^{w} + \alpha_{i^b} + c_{i^b j}$ in market j, then imports to this market would originate through Kano.

Finally, in simultaneously solving for the sequence of equations and complementarity relationships in equations (1) through (6), we can determine an optimal solution in the variables Q_{kj}^{d}, Q_{ki}^{s}, X_{ijk}, and M_{2i}, inclusive of regional disaggregation by rural or urban area. Results are aggregated across six geopolitical regions among the 47 states of Nigeria (Appendix Table A.5).

The data for model parameters and validation are based on various secondary sources and the fieldwork of the authors. Production data were taken from the National Agricultural Extension and Research Liaison Services (NAERLS) of 2009 (NAERLS, 2009); demand data at the regional level were from the Consumption Patterns in Nigeria, 2009/2010, dataset of the National Bureau of Statistics (NBS), adjusted by population statistics; and prices were also from the NBS for 2012 and 2010 for both local and imported rice. Nigerian government documents provided the country's national objectives and targets for improving the rice sector.

Price elasticities used in the model were taken from various sources. The own-price elasticities of demand for both types of commodities (standard and premium rice) and for urban and rural areas are from Gyimah-Brempong and Kuku (forthcoming).[9] These are presented in Appendix Table A.1. The cross-price elasticities in Table A.1 were derived from demand shares of each type of rice in total rice consumed at the national level in urban and rural areas and the own-price elasticities. We chose to include these to allow for some substitutability between the two types of rice rather than assuming away any cross-price effects. The own-price elasticity of supply for local standard rice was assumed to be 0.2 as in Diao, Johnson, and Takeshima (forthcoming) and the review by Rahji and Adewumi (2008). For domestic premium rice, a value of 0.8 was used, considering that in order to meet demand large-scale millers use their existing capacities to mill imported brown rice if local paddy rice is unavailable (Johnson, forthcoming). Appendix Table A.2 presents the values of own- and cross-price elasticities of supply used. Because of uncertainties surrounding parameter values of elasticity estimates, we adjust these later in Section 5 to test the sensitivity of the model to any changes in these parameter values.

Freight and transportation costs are calculated using unit costs and actual distances in kilometers between state capitals. Average unit freight costs for the six geopolitical zones are presented in Appendix Table A.3. Freight costs to import rice via Kano are based on the overland distance by road from the port of Cotonou in Benin to Kano via Niger (a total distance of 1,684 km) and a unit transportation cost that is assumed to be 50 percent more than in the southern parts of Nigeria from the port of Lagos: 33.71 N/mt/kg. This includes higher gasoline costs (about 20 percent higher according to globalpetrolprices.com) and an additional 30 percent for smuggling transaction costs.

Due to the unavailability of sufficient data for rural and urban marketing costs, these were weighted by distance between states and whether trade is urban to urban, urban to rural, rural to urban, or rural to rural. The choice of using distance-related costs was to distinguish cost differences in marketing in each state based on source and destination. Within each state, additional costs were added to distinguish between rural and urban in either direction (assumed to be asymmetrical—with higher costs

[9] Although Gyimah-Brempong and Kuku (forthcoming) publish estimates at the national level only, we were able to obtain disaggregated estimates when sufficient data were available using their linear expenditure system regression model at the level of geopolitical region, as displayed in Table A.5 in the Appendix.

for rural marketing). These marketing costs are presented by geopolitical zone in Appendix Table A.4. Costs are doubled in the North East geopolitical zone to account for its relative isolation given the current adverse security situation, while in the South West zone, costs are assumed to be much lower, at 70 percent below calculated values. Later, in Section 5, we also adjust the overland freight and rural marketing costs separately to test for the sensitivity of model results in terms of the range of tariff rates at which all imports will shift from Lagos to Kano.

The model is calibrated to reflect Nigerian rice markets in 2009. Because a tariff rate of 40 percent existed at the time, the base model was calibrated to closely resemble actual observed values at the time with respect to quantities demanded and supplied, including import volumes. Final prices determined by the base model were also checked for their reasonableness based on observed prices, for which 2009 data were available. Table 3.1 presents the final base model results as compared with actual values of total demand, supply, and import quantities for both types of rice commodities. With the exception of domestic premium rice production, the model validation is reasonable for the base case scenario, with a percentage difference between observed values and base model results ranging between 1.0 and 5.1 percent in absolute terms for each of the key endogenous variables.

Table 3.1 Comparing base model results with observed quantities of demand (rural and urban), production, imports, and total supply, by type of rice, thousands of mt

Type of rice	Observed	Base model	Percentage difference
Demand *('000 metric tons)*			
Standard, rural	2,226	2,322	4.3
Standard, urban	583	556	-4.5
Premium, rural	1,198	1,137	-5.1
Premium, urban	1,359	1,417	4.3
Production *('000 metric tons)*			
Local standard	2,808	2,878	2.5
Local premium	749	713	-4.8
Total rice	3,557	3,591	1.0
Imports *('000 metric tons)*			
Imported premium [a]	1,809	1,841	1.8
Supply *('000 metric tons)*			
Production + imports	5,366	5,432	1.2

Source: Authors' Nigeria spatial rice market model.
Notes: [a] The base model results show about 7.4 percent of this amount (about 138,500 metric tons) being imported through Kano, a reasonable result considering traditional trade linkages with Niger among traders in the north.

4. SIMULATION RESULTS

In this section, we present model simulation results under two alternative import trade regimes:

- no smuggling, in which all rice imports face import tariffs at the border (mainly Lagos port), and
- cross-border smuggling through the Niger-Nigeria border near Kano.

In describing the results for each trade regime, we first discuss national-level results and then describe the regional effects within Nigeria of tariff policies under these alternative trade regimes.

Effects of Tariff Changes with No Smuggling

In the no-smuggling scenario, increasing rice tariffs results directly in corresponding increases in imported rice prices and reductions in imports (Table 4.1). At a zero tariff, imports reach 3.2 million tons with rising demand as prices fall, almost double the level in the base case (40 percent tariff). Imports do not entirely displace local production, however, as prices for local varieties in some of the more distant markets would still remain competitive with imports coming from Lagos, given high transportation and marketing costs for imported rice.

Table 4.1 Production, consumption, imports, and prices of premium and standard rice by tariff regime, no-smuggling scenario

	Premium rice (by tariff regime)			*Percent change*	Standard rice (by tariff regime)			*Percent change*
Region	0	40*	120	*40 -> 120*	0	40*	120	*40 -> 120*
Consumption ('000 metric tons)								
Central	512	347	190	*-45.3*	206	455	687	*51.2*
North	1,200	869	589	*-32.2*	886	1,256	1,560	*24.2*
South	2,331	1,326	235	*-82.3*	524	1,185	1,892	*59.6*
National	**4,043**	**2,541**	**1,014**	***-60.1***	**1,617**	**2,896**	**4,139**	***42.9***
Production ('000 metric tons)								
Central	70	159	233	*46.6*	565	918	1,262	*37.5*
North	188	338	481	*42.1*	1,006	1,616	2,199	*36.0*
South	144	224	300	*34.2*	46	362	679	*87.6*
National	**401**	**721**	**1,014**	***40.6***	**1,617**	**2,896**	**4,139**	***42.9***
Imports ('000 metric tons)								
Via Lagos	**3,641**	**1,820**	**0**	***-100.0***	NA	NA	NA	*NA*
Average urban prices (naira/kg)								
Central	113.1	150.7	186.3	*23.6*	99.7	102.8	105.6	*2.7*
North	122.5	159.7	192.5	*20.5*	100.7	103.2	105.8	*2.5*
South	109.9	147.9	187.7	*26.9*	104.9	107.5	110.4	*2.7*
National	**114.7**	**152.5**	**189.1**	***24.0***	**102.5**	**105.1**	**107.9**	***2.6***
Average rural prices (naira/kg)								
Central	127.2	165.6	202.0	*22.0*	87.2	90.1	92.8	*3.1*
North	134.7	172.2	205.0	*19.0*	89.8	92.3	94.8	*2.7*
South	122.5	160.9	200.1	*24.4*	100.6	103.2	106.1	*2.7*
National	**127.5**	**165.6**	**202.1**	***22.0***	**94.5**	**97.1**	**99.8**	***2.8***

Source: Authors' Nigeria spatial rice market model simulations.
Note: * The 40 percent tariff regime is the base case scenario.
The central region corresponds to the North Central geopolitical zone, the north region to the North West and North East zones, and the south region to the three southern geopolitical zones.

The average domestic price for premium rice in urban areas rises from about 152.5 N/kg when the tariff rate is 40 percent to 189.1 N/kg when the rate reaches 120 percent. For standard ordinary rice, prices rise, but more slowly, from 105.1 to 107.9 in urban areas and 97.1 to 99.8 in rural areas. Given higher domestic prices, domestic production rises, and imports of premium rice are gradually replaced by local premium rice, as domestic production of premium doubles from a base of 0.72 million (with 40 percent tariff) to about 1.01 million tons at the tariff rate of 120 percent. Production of ordinary rice increases even more, from 2.9 to 4.1 million tons, raising total production to 5.1 million tons at tariff rates above 93 percent—equal to total domestic demand at the tariff-induced higher domestic prices, and thus achieving self-sufficiency as consumers shift toward the standard rice variety. Total demand actually falls by 300,000 tons, from 5.4 million tons.

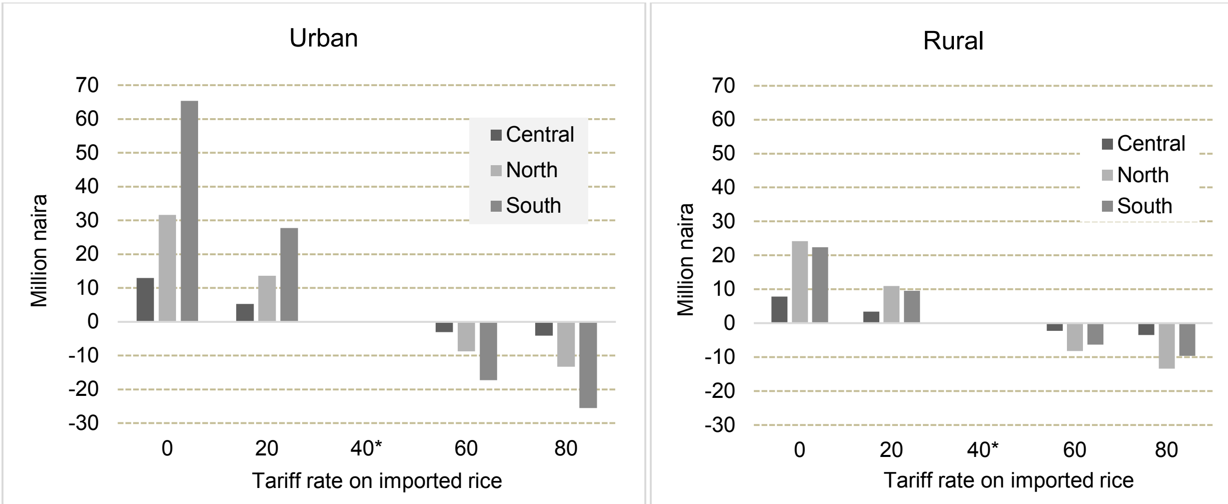
How prices change by location, whether urban or rural, as a result of import tariff policies will vary and have important implications on production and demand for each type of rice. Referring back to Table 4.1, as import tariffs for premium rice are raised from the base of 40 percent to 120 percent, domestic prices for this variety rise by 24.0 percent nationally in urban areas (which have the greatest demand) and 22.0 percent in rural areas. The lower rise in prices in rural areas reflects the fact that prices are already higher in rural areas due to transport and marketing costs, so the proportional effect of a change in tariff is smaller because these margins are affected only by the volume traded. Additionally, rural consumers are more likely than urban consumers to shift to local standard rice varieties.

There are also differences between the central, northern, and southern regions, as one would expect. Urban prices actually rise slightly less in the north than in the south, 20.5 percent versus almost 26.9 percent in the south. The central region experiences a decline of 23.6 percent. This is because both the central region and the north supply a significant amount of locally produced premium rice (especially in Kano) to the central region, while the south relies more on imports from the north or the world market. Rural prices follow similar patterns, although with lower price changes relative to urban areas. This is primarily due to the fixed higher transportation and marketing costs not directly affected by tariffs. Finally, given the assumption of weak substitution between the two types of rice, prices for standard rice rise only marginally relative to those of premium rice, which the tariff directly targets (a change of about 2.5 to 3.1 percent). The small change in price is also quite similar across all regions and in both rural and urban areas.

The impact on production is obviously affected by the effect of the tariff on prices and subsequently on demand, all of which vary by location. Prices for standard rice rise marginally with higher tariffs. This can be explained by the increase in demand as some consumers switch from premium rice in favor of the cheaper standard variety. At the higher tariff rate, demand for premium rice declines by 60 percent, while it increases for standard rice by 42 percent. Much of the substitution occurs in the south, which has more to lose when prices rise with higher tariffs.

These changing patterns of quantity demanded and equilibrium prices for each type of rice have important implications for household welfare, whether in rural or urban areas. For example, the decline in demand for premium rice as prices rise hurts urban households the most because they are the least likely group of consumers to substitute toward the cheaper, standard variety. Only producers of the premium variety—large-scale millers in urban areas—benefit. In rural areas, on the other hand, the shift by a majority of consumers toward buying the cheaper standard rice alternative lessens the overall negative impact of the higher tariff on rural welfare relative to that of urban areas, and even more so if the area has many net sellers of standard rice. Figure 4.1 shows the change in net social welfare across geographic regions and urban versus rural areas as tariffs are raised. Because the south is mostly made up of net buyers, this is the region most likely to lose on net with higher prices—and even more so in urban areas. Notice in Figure 4.1 the much higher welfare changes for the urban versus the rural population in the southern region compared with the other two regions.

Figure 4.1 Change in net producer and consumer welfare in rural and urban areas due to tariff changes, no-smuggling scenario, for all rice, million naira

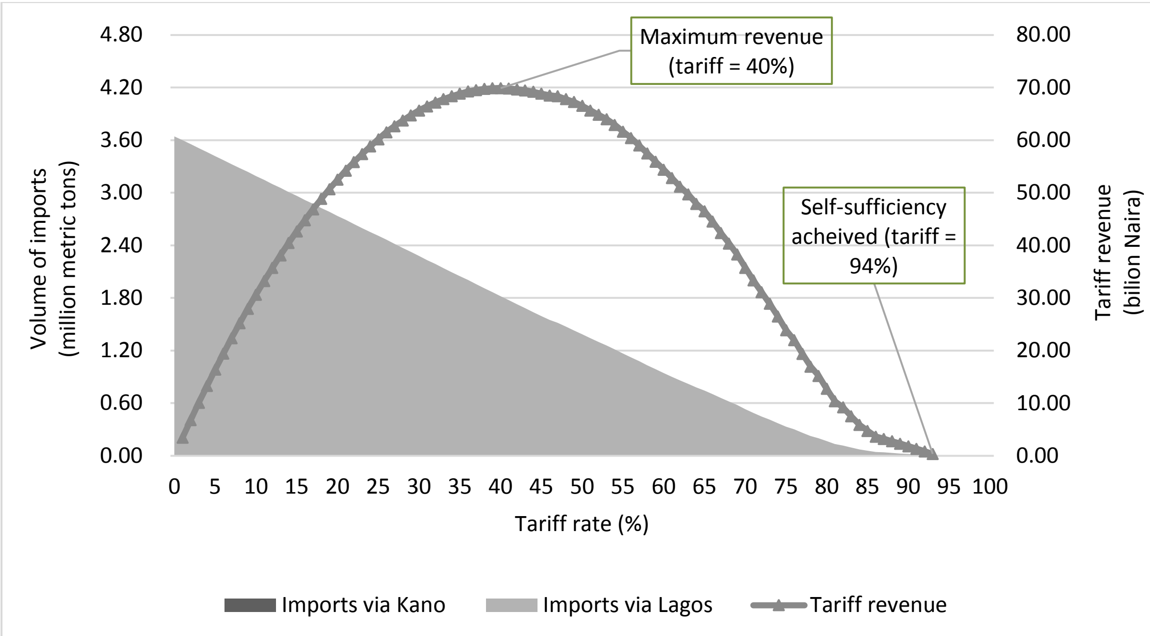


Source: Authors' Nigeria spatial rice market model results.
Note: * The initial tariff rate was 40 percent; hence the absence of any change in welfare at this tariff level.

Among urban consumers, poorer households suffer the most because food purchases account for a much higher proportion of their income. In the major rice-producing areas in the central and northern regions, the net effect on rural and urban welfare is about the same, because both areas produce rice—the standard variety in rural areas and premium rice in urban areas. The majority of beneficiaries in rural areas will be the net sellers, the rice paddy farmers, and the small-scale millers. The increase in demand for and prices of the local standard variety, as consumers shift away from the more expensive premium variety, stimulates this sector to produce more.

Finally, considering the tariff rates at which government can maximize tariff revenues or achieve the self-sufficiency policy goal under our scenario with no smuggling (all imports pass through Lagos), these are 40 percent and 94 percent, respectively (Figure 4.2). Beyond the 40 percent mark, any further increase in tariffs reduces demand for rice imports by a greater percentage than the percentage increase in tariffs. Although the country can achieve the self-sufficiency goal at the tariff rate of 94 percent, this occurs at the expense of consumer welfare, as pointed out earlier.

Figure 4.2 Total imports and tariff revenues, no-smuggling scenario



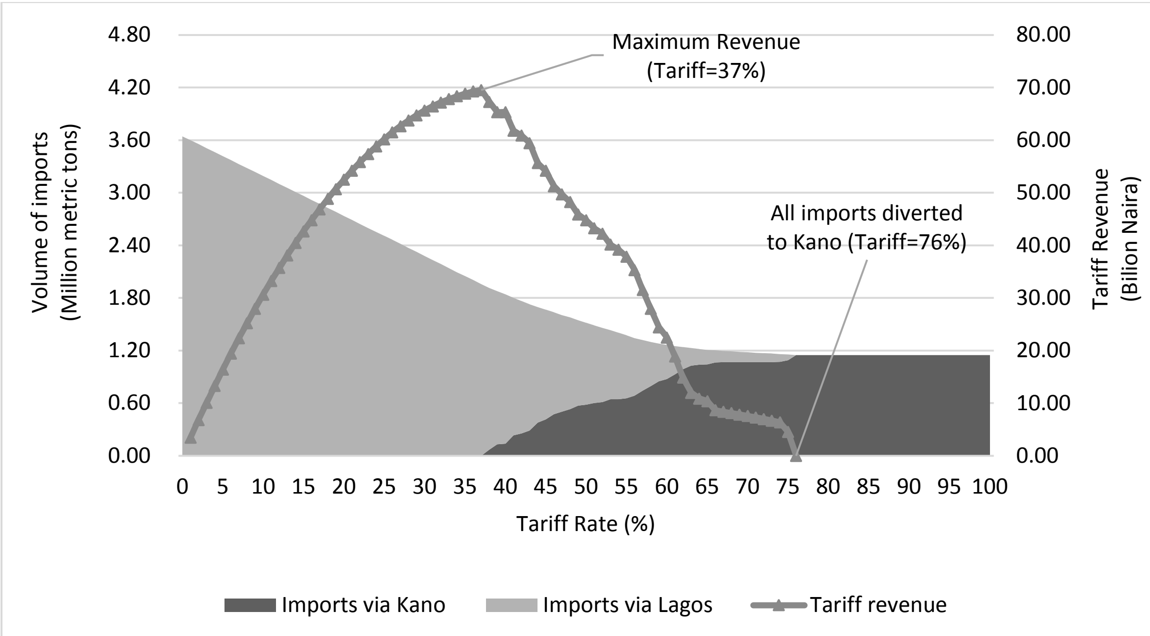
Source: Authors' Nigeria spatial rice market model simulation results.

Effects of Tariff Changes with Smuggling

So far we have considered the situation in which a tariff policy is completely effective and official rice import channels are used—that is, all imports pass through Lagos and are reported. We now introduce the option to divert imports through Kano, a channel that avoids the tariff but requires rice smugglers to pay higher freight costs to ship overland through Benin and Niger. We also look at trade flows between regions in Nigeria, comparing both scenarios—with and without smuggling. At some point, as tariffs rise, even with the more costly shipping channel that avoids tariffs through Benin and Niger, an import parity price will result in Kano that is lower than that of the rice imported via Lagos. Based on information obtained through field observations, this is a situation that was close to the reality in Nigeria in 2013 when tariff rates had increased to 110 percent.

Figure 4.3 presents the volume of imports through both Lagos and Kano. At the initial 40 percent base tariff, Kano already imports a small amount of premium rice from world markets, but a very small amount. Evidently, a 37 percent tariff proves to be a critical point at which the cost of importing through Kano is about equal with that of Lagos (the costs of the former mostly in land transportation and marketing costs via Benin and Niger, and the costs of the latter affected by the tariff, land transportation, and marketing from the south to the north in Nigeria). With smuggling, it is at rice tariffs higher than 37 percent that tariff revenues begin to fall significantly relative to the scenario that has no smuggling. The import share of total rice consumed in Nigeria at this tariff threshold would be 36 percent. At the 76 percent tariff rate, all imports come though Kano and tariff revenues fall to zero. In the end, with smuggling, Nigeria is able to attain a self-sufficiency ratio of only about 78 percent, short of its self-sufficiency policy goal in rice production. In other words, Nigeria would still have to import about 22 percent of its rice consumption needs.

Figure 4.3 Total imports via Kano and Lagos, and tariff revenues, smuggling scenario



Source: Authors' Nigeria spatial rice market model simulation results.

As in Table 4.1 earlier, Table 4.2 presents for the smuggling scenario a breakdown of production, consumption, imports, and prices by region for both premium and standard rice. As before, imports are partially replaced by increased production of local premium rice as prices rise, an increase of 12 percent (713,000 to 802,000 tons) at the 76 percent and higher tariff rates (also see Figure 4.3). Total demand decreases less for premium rice than without smuggling as prices are maintained at lower levels due to smuggling. This time, the substitution away from premium to standard does not occur as much. Evidently, the smaller rise in premium prices causes fewer premium rice consumers to shift toward the cheaper standard rice variety.

With respect to prices, as import tariffs for premium rice rise from the base of 40 percent to 120 percent (or at the threshold of 76 percent, discussed above, where tariffs are no longer effective), domestic prices for premium rice in urban areas rise by only about 7.5 percent relative to the 24 percent seen in the no-smuggling scenario. However, the southern region experiences far greater increases in price (12.3 percent) relative to the northern (only 1.7 percent) and central (6.8 percent) regions, especially when tariffs rise above 76 percent and all imports come through Kano. The difference captures the greater transporting and marketing costs associated with moving imported rice through Kano to markets in the south. A similar trend occurs in rural areas, but at much higher prices.

There is only a marginal effect on the price for standard rice in all regions—about a 3 percent increase—under the smuggling scenario. The smaller price changes for premium rice in the northern region are expected due to the flow of imports through Kano in the north, together with a greater capacity for milling of local premium rice. The additional cost of transporting and marketing this rice to the southern region explains the higher rate of price increases in the south, because prices are initially lower there. Naturally, the only exception is when tariffs are removed altogether—which would be equivalent to the alternative scenario considered, of no smuggling.

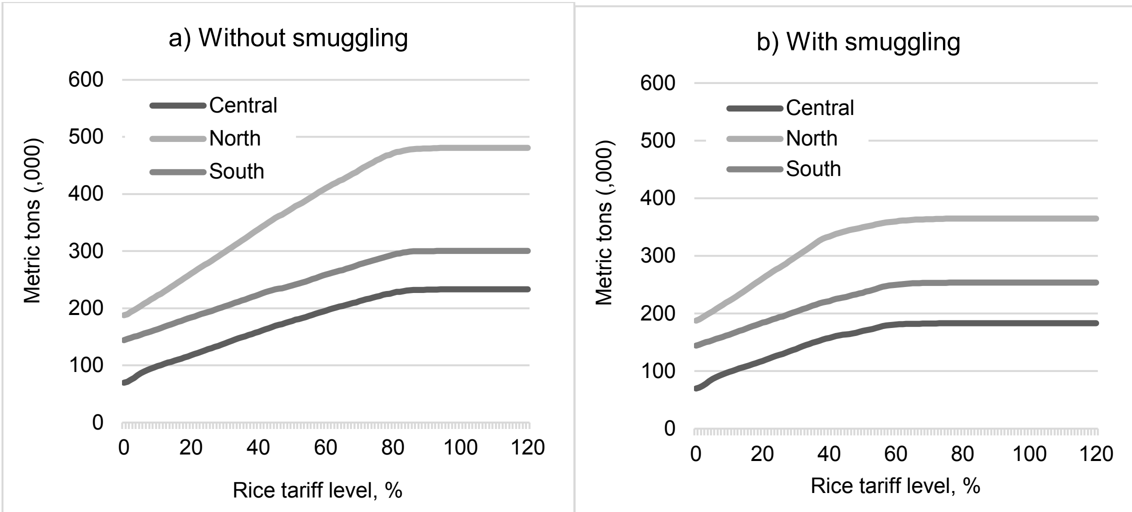
Table 4.2 Production, consumption, imports, and prices of premium and standard rice by tariff regime, with-smuggling scenario

Region	Premium rice (by tariff regime) 0	40[a]	120	Percent change 40 -> 120	Standard rice (by tariff regime) 0	40[a]	120	Percent change 40 -> 120
Consumption ('000 metric tons)								
Central	512	349	311	*-10.9*	206	451	498	*10.3*
North	1,200	879	880	*0.1*	886	1,241	1,225	*-1.4*
South	2,331	1,327	759	*-42.8*	524	1,185	1,516	*27.9*
National	**4,043**	**2,554**	**1,949**	***-23.7***	**1,617**	**2,878**	**3,238**	***12.5***
Production ('000 metric tons)								
Central	70	158	183	*16.4*	565	915	1,028	*12.3*
North	188	334	365	*9.3*	1,006	1,601	1,721	*7.5*
South	144	222	254	*14.5*	46	362	489	*35.4*
National	**401**	**713**	**802**	***12.5***	**1,617**	**2,878**	**3,238**	***12.5***
Imports ('000 metric tons)								
Imports via Lagos	**3,641**	**1,702**	**0**	*-100.0*	NA	NA	NA	*NA*
Imports via Kano	**0**	**139**	**1,147**	*724.5*	NA	NA	NA	*NA*
Average urban prices (naira/kg)								
Central	113	150	161	*6.8*	100	103	104	*1.2*
North	122	159	162	*1.7*	101	103	104	*1.0*
South	110	148	166	*12.3*	105	108	109	*1.3*
National	**115**	**152**	**163**	***7.5***	**102**	**105**	**106**	***1.2***
Average rural prices (naira/kg)								
Central	127	165	174	*5.3*	87	90	91	*1.4*
North	135	171	172	*0.9*	90	92	93	*1.0*
South	122	161	178	*10.7*	101	103	105	*1.3*
National	**128**	**165**	**175**	***6.2***	**94**	**97**	**98**	***1.2***

Source: Authors' Nigeria spatial rice market model simulations.
Notes: NA = not applicable. [a] The 40 percent tariff regime is the base case scenario. The base model results show about 7.4 percent of imports (138,500 metric tons) being imported through Kano, a reasonable result considering observed trade linkages with Niger among traders in the north. The central region corresponds to the North Central geopolitical zone, the north region to the North West and North East zones, and the south region to the three southern geopolitical zones.

Given the reduced effect of higher tariffs on prices, production will not respond as much as it does if the tariffs were effective (without smuggling). Figure 4.4 shows total production of local premium rice as tariffs change under both scenarios—with and without smuggling. Higher tariffs provide greater incentives for local producers to expand output when the tariffs are effective, while a zero tariff would force many of out of business. But the size of the effect varies by region, with production volumes in the northern region increasing at more than twice the volume of the south. Rice producers in the central region, on the other hand, respond at a slower rate despite producing a significant amount of standard local rice (and paddy rice in general). This is because farmers in the central region produce less premium rice as the region has fewer large, modern millers than the North (Johnson, forthcoming). At the same time, the central region is also better able to take advantage of any tariff evasion above the 37 percent optimal tariff by importing premium rice from the north instead of the south.

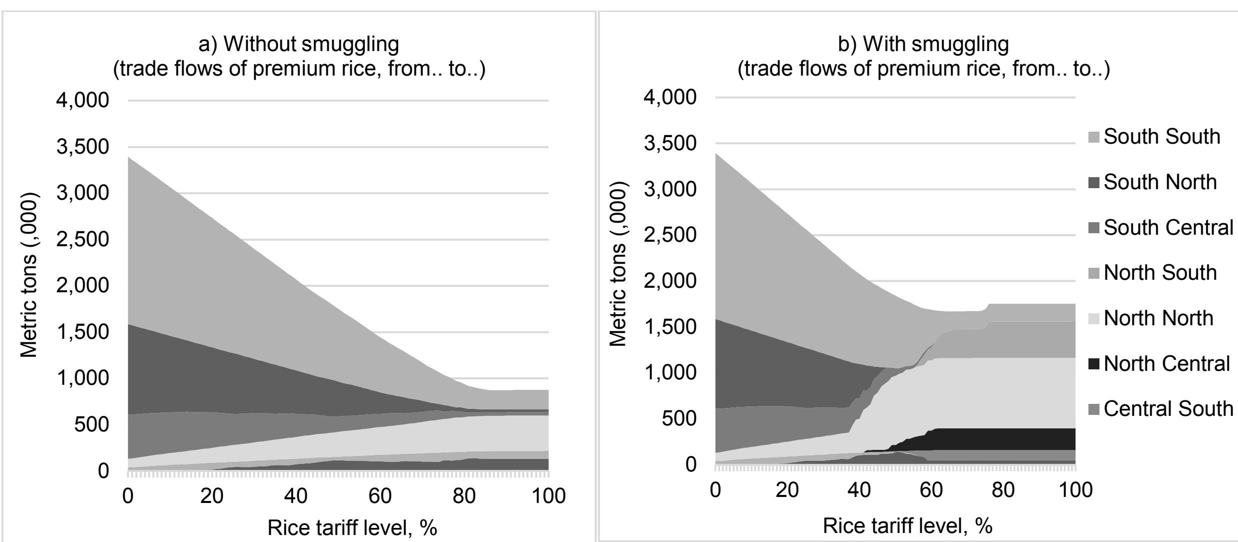
Figure 4.4 Total production of local premium rice by tariff level, with and without smuggling



Source: Authors' Nigeria spatial rice market model simulation results.

The effect of the two scenarios on the volume of premium rice transported between regions to meet demand can be quite significant, with important implications on the direction of trade, in particular for the central region. Figure 4.5 presents the trade flows between regions and within states in the same region for premium rice (total of imported and locally produced) as tariffs rise under both scenarios. The totals are less than in Figures 4.2 and 4.3 because here we are measuring only the amount transported from one area to another, for example, urban to rural within a state where it is produced or transported out of state.

Figure 4.5 Volume of premium rice transported between regions as tariffs change under the with- and without-smuggling scenarios



Source: Authors' Nigeria spatial rice market model simulation results.

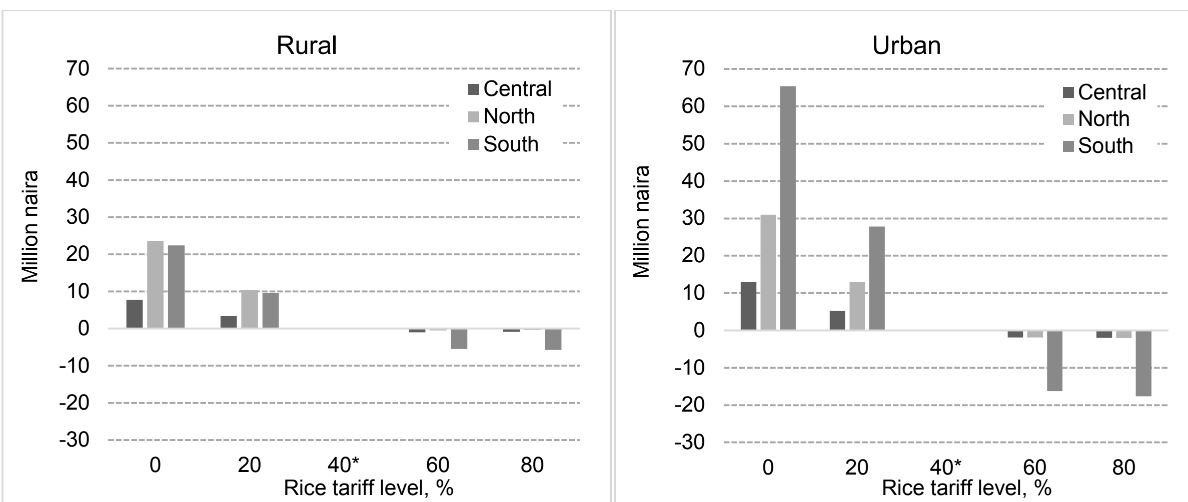
Notes: Total of imported and locally produced premium rice. The shaded portions in the figure reflect total volumes of trade flows in premium rice. In the legend category for each shaded portion, the first region is the source and the second region is the destination. If the source and destination regions are the same, this measures trade flows between states within a single region, for example, "South South" would include trade between Lagos and Oyo states. See Appendix Table A.5 for the states in each region.

Referring to Figure 4.5 under the smuggling scenario, premium rice exports from the north increase substantially from about 37 percent until the 76 percent tariff rate is reached. This is due to excess supply in a combination of imported and locally produced premium rice. The north and central regions combined ship more than half a million tons of premium rice to the south at a 76 percent tariff rate, compared with none at all when all imports pass through Lagos—indeed, the flow in premium rice is the reverse when all imports come through Lagos. For standard rice (not shown here), under the smuggling scenario exports from north to south increase from 514,000 to 646,000 tons, a difference of about 150,000 tons. It is less profitable to ship rice to some areas of Nigeria since prices do not rise as much as they do when tariffs are effective. All in all, the dramatic decline in the volume of premium rice traded across regions as tariffs rise is dampened as tariffs become ineffective at 76 percent and higher, which ultimately benefits traders and consumers alike.

An interesting result observed in Figure 4.5 is the increased flow of premium rice transported to the central region from the north and the reduction in premium rice coming to the central region from the south when tariffs fall within the range of 52 percent to 57 percent under the smuggling scenario. In general, the north experiences increasing volumes of trade within its region as tariffs rise above 37 percent, and then begins to export larger volumes of premium rice to the other two regions as the tariff rate continues to rise. The kink in total volumes traded at the 76 percent tariff mark occurs when all imports start coming through Kano only.

Figure 4.6 presents the changes in net producer and consumer welfare in urban and rural areas with smuggling. Compare this with Figure 2.2, showing how net welfare losses from rising prices are not felt as deeply as they are without smuggling, especially in the north and central regions. However, the south still experiences relatively higher economic losses than the other two regions, as prices for premium rice rise to levels higher than in the north. Demand for rice in the south is increasingly met by transporting rice from the north.

Figure 4.6 Change in net producer and consumer welfare in rural and urban areas due to tariff changes, smuggling scenario, for all rice, million naira



Source: Authors' Nigeria spatial rice market model simulation results.
Note: * The initial tariff rate was 40 percent; hence the absence of any change in welfare at this tariff level.

The policy goal of achieving self-sufficiency is not possible with smuggling. Even if the government can successfully curtail smuggling in order to achieve self-sufficiency by imposing higher tariff rates—94 percent or higher according to our estimates—this achievement would come at great costs to society. These costs are illustrated in Figure 2.2 with respect to declining net social welfare at higher tariff rates. Moreover, the cost to Nigeria of policing its extensive borders to curtail smuggling could be enormous, putting a drain on scarce government revenues needed to invest in the domestic rice sector in the first place. In addition, tariff revenues would disappear as rice imports dry up.

5. SENSITIVITY ANALYSIS

The challenge in using spatial equilibrium simulation models is ensuring that the results are credible and robust given the model's underlying assumptions and parameter values. To check credibility and robustness, several simulations were conducted by changing key parameters in the model under the with-smuggling scenario. Specifically, parameter values were both increased and reduced by up to 50 percent from their initial values in increments of 10 percent. The selected parameters were as follows:

1. Own- and cross-price elasticities of demand
2. Own- and cross-price elasticities of supply
3. Freight and transportation costs overland (via Benin and Niger)
4. Internal marketing costs for intraregional trade

Percent root mean square errors (%RMSEs) were computed to compare the results from the range of changes in each parameter value relative with the results of the model with initial values.

First, changing the values of own- and cross-price elasticities of demand equally across regions results in very little change in the results at any given tariff rate, aside from producer welfare in rural areas. This is most likely due to our higher cross-price elasticities of demand in rural versus urban areas. Nevertheless, it has no effect on the shifting of imports from Lagos to Kano nor on the tariff rate at which revenues or the self-sufficiency ratio is maximized. Because we are more confident of the source for the demand elasticity estimates, and considering the effects on welfare changes are limited relative to the percent changes in the elasticity values, the model is sufficiently robust with respect to these values.

For own- and cross-price supply elasticity values, small incremental changes are found to be less robust, resulting in some significant effects on model results. Average %RMSEs are highest for standard rice production in the south (27.0 percent) and premium rice production in the central region (13.7 percent). Producer welfare in rural areas is also significantly affected, with %RMSEs ranging between 39.6 and 67.7 percent. Hardly any change occurs in the tariff rate at which all imports flow through Kano. A maximum self-sufficiency ratio is achieved at tariff rates 10 to 17 percentage points lower than in initial model results.

These higher sensitivities to own- and cross-price supply elasticity values appear primarily because of our assumptions on cross-price elasticities between standard and premium rice. A positive cross-price elasticity implies that a small change in the price of one type of rice affects the supply of the other as well. Setting them to zero results in much lower impact on the model results overall. Evidently, while the assumptions we make on cross-price elasticity values of supply are critically important for determining producer welfare and the maximum achievable self-sufficiency ratio, the model results are less affected when all import flows shift to Kano. Nevertheless, it is clear that the supply elasticities used in the model are less robust than the demand elasticities used. In order to improve the results of this model, further research is needed to estimate their correct empirical values in the case of Nigeria.

Of particular relevance to our model results is the cost of overland freight charges for rice imports flowing through Kano, which will naturally affect the tariff rate at which imports will increasingly become diverted through the north via Kano. From Table 5.1, it is evident that lowering the freight costs by 50 percent dramatically reduces the tariff rate at which imports begin to flow through Kano, from 38 to 7 percent. With these lower freight costs, all imports flow through Kano at a tariff rate of 47 percent, compared with the initial 76 percent. Furthermore, maximum tariff revenues occur at a lower tariff rate, 25 percent, compared with 37 percent before—with import shares of 50 percent. On the other hand, if freight costs are 50 percent higher, maximum tariff revenues will still occur at about 40 percent and with import shares at about 33 percent. Under these higher freight costs, at a 92 percent tariff rate, all imports flow through Kano.

Table 5.1 Sensitivity of shifts in import flows via Kano by tariff rate due to changes in overland freight costs via Benin and Niger

	Tariff level, %			%RMSE	
Threshold	Freight costs used in initial model	50% lower freight costs	50% higher freight costs	Tariff < 40%	Tariff > 40%
Tariff level at which imports begin via Kano	38	7	74	0.0	78.6
Tariff level at which all imports are via Kano	76	47	92	16.5	0.0
Tariff level at which maximum tariff revenue is achieved	37	25	40	16.9	116.6
Tariff level at which maximum self-sufficiency in rice production for Nigeria is achieved	78	47	79	NA	NA

Source: Authors' Nigeria spatial rice market model simulation results.
Notes: %RMSE = percent root mean square error; NA = not applicable.

Producer welfare and consumer welfare are also affected by our assumptions on overland freight costs, especially in the central region, because the shift in imports from Lagos to Kano occurs at much lower tariff rates with lower freight costs or at higher tariff rates with higher freight costs (Table 5.2). The highly sensitive nature of the model to changes in overland freight costs for imports flowing through Kano is to be expected, because the model defines the import parity price of imported rice from this source in a particular local market. If this price is lower than the import parity price of rice imported into this market through official channels, through the port at Lagos and hence including the tariff, then consumers would prefer to purchase the lower-priced imports coming through Kano.

Table 5.2 Sensitivity of changes in demand, production, and consumer and producer welfare due to changes in overland freight costs via Benin and Niger, average percent root mean square errors

	Demand for premium rice		Production of rice		Consumer welfare		Producer welfare	
Region	Tariff < 40%	Tariff > 40%	Tariff < 40%	Tariff > 40%	Tariff < 40%	Tariff > 40%	Tariff < 40%	Tariff > 40%
Urban								
Central	1.9	19.1	2.9	16.7	40.2	-83.7	-44.5	91.0
North	3.6	16.7	4.2	17.2	65.8	-124.9	-68.2	130.8
South	0.4	35.1	1.3	11.0	16.1	-61.3	-24.3	74.4
Rural								
Central	2.6	22.5	1.6	12.9	45.1	-89.6	-24.8	69.4
North	4.0	17.0	3.3	14.8	69.6	-136.3	-33.0	74.4
South	1.4	44.8	2.3	24.8	26.4	-73.3	-26.0	70.2

Source: Authors' Nigeria spatial rice market model simulation results.

Finally, we also consider the sensitivity of our assumed marketing costs for intraregional trade in rice. We find that at lower tariff rates urban producers of premium rice are more affected because they sell a significant portion of their rice to rural areas, a trade that is highly sensitive to transport and marketing costs. This can be observed by the greater sensitivity of rice production and producer welfare in urban areas, and overall consumer welfare in both urban and rural areas. Production of standard rice is less affected because much of it is consumed where it is produced in rural areas. The tariff rate at which import flows occur though Kano is less affected by marketing costs for rice in Nigeria.

6. CONCLUSIONS AND POLICY IMPLICATIONS

In Nigeria, the introduction of higher import tariffs for rice has not succeeded in stimulating local production nor in achieving the country's policy goal of self-sufficiency in rice. In large part, this is due to underinvoicing of imports or the diversion of imports by smuggling through the country's porous borders. In particular, high rice tariffs not only increase incentives for underinvoicing at the major port, Lagos, but also increase incentives for smuggling through Benin and Niger, over Nigeria's northern border. Under these conditions, changes in tariff rates have a complex set of effects on production, prices, and trade flows that vary across space and reduce the effectiveness of tariffs as a policy instrument for promoting domestic rice production.

In this paper, we utilize a spatial multimarket model for Nigeria's rice trade that explicitly incorporates incentives for informal trade and volumes of rice import flows through both formal and informal channels. Results show that welfare is maximized when marketing costs for rice flows through Benin and Niger that evade the import tariff are equal to the import parity price of rice that flows through official channels from Lagos to northern Nigeria, incurring import tariffs. The optimal welfare-maximizing tariff is calculated to be between 25 and 40 percent, depending on the model parameter values used. Rice import tariff rates in excess of this optimal range lead to increased welfare losses for consumers in the south while dampening the effect of the tariff on prices and consumer welfare in both the central and northern regions.

Maintaining tariff rates at the welfare-maximizing level not only prevents further welfare losses to the rice economy but, by maximizing tariff revenues, generates resources that in principle could be used to increase public investment in rice productivity. Note, however, that in the absence of increases in productivity, rice imports would account for 33 to 50 percent of total rice supply in Nigeria at the optimal tariff levels. Even if smuggling could be totally eliminated and higher tariffs were enforced, self-sufficiency in rice would require a tariff rate of about 94 percent or higher. Such a policy would be politically infeasible given its large negative effects on poorer consumers and on overall economic welfare. Thus, as long as smuggling cannot be prevented, a policy of avoiding excessively high tariff rates, that is, greater than about 40 percent, while investing more to increase rice productivity and the competiveness of local rice production and milling technologies, is the most feasible long-term option for Nigeria to one day approach rice self-sufficiency.

APPENDIX: MODEL PARAMETERS AND INITIAL DATA

Table A.1 Own- and cross-price elasticities of demand (ε_{dij}) used in model, by geopolitical zone

Zone*	ε_{d11}	ε_{d12}	ε_{d21}	ε_{d22}
Rural				
North Central	-0.223	0.360	0.829	-0.446
North East	-0.334	0.540	0.982	-0.529
North West	-0.446	0.720	1.113	-0.600
South East	-0.183	0.296	0.387	-0.208
South South	-0.372	0.602	0.782	-0.421
South West	-0.241	0.389	0.509	-0.274
*Weighted ave**	*-0.329*	*0.531*	*0.855*	*-0.460*
*Estimated**	*-0.330*			*-0.460*
Urban				
North Central	-0.088	0.205	0.177	-0.412
North East	-0.132	0.307	0.186	-0.434
North West	-0.176	0.409	0.211	-0.492
South East	-0.101	0.236	0.092	-0.215
South South	-0.176	0.411	0.167	-0.389
South West	-0.114	0.265	0.109	-0.253
*Weighted ave**	*-0.131*	*0.306*	*0.146*	*-0.341*
*Estimated**	*-0.129*			*-0.340*
National				
*Weighted ave**	*-0.288*	*0.484*	*0.708*	*-0.436*
*Estimated**	*-0.240*			*-0.470*

Source: Authors.

Notes: $\varepsilon_{dij} = \left[\frac{dQD_i}{dP_j}\frac{P_j}{QD_i}\right], \forall ij = 1,2$ (where 1 = standard local rice, and 2 = premium rice, local and imported).

* Weighed by regional share of total demand and comparable with estimated values from Gyimah-Brempong and Kuku (forthcoming).

Table A.2 Own- and cross-price elasticities of supply (ε_{sij}) used in model, by region

	Standard (rural)		Premium (urban)	
Region	ε_{s11}	ε_{s12}	ε_{s21}	ε_{s22}
Central	0.200	1.040	0.150	0.800
North	0.200	0.910	0.180	0.800
South	0.200	0.290	0.550	0.800

Source: Authors.

Note: $\varepsilon_{sij} = \left[\frac{dQS_i}{dP_j}\frac{P_j}{QS_i}\right], \forall ij = 1,2$ (where 1 = standard local rice, and 2 = premium rice, local and imported).

The cross-price elasticities were calculated using the own-price elasticities and the shares of each type of rice in total rice production, as follows:

$\varepsilon_{s12} = \varepsilon_{s11} \cdot \left(^{S_1}/_{S_2}\right)$; $\varepsilon_{s21} = \varepsilon_{s22} \cdot \left(^{S_2}/_{S_1}\right)$, where s_1 and s_2 are the shares of standard (c1) and premium (c2) in total rice production, respectively. Central region corresponds to the North Central geopolitical zone. North region aggregates the North East and North West zones. South region is made up of the three southern zones.

Table A.3 Average unit freight costs used in model, by geopolitical zone, Naira/mt/km

North Central (NC)	North East (NE)	North West (NW	South East (SE)	South South (SS)	South West (SW)
17.96	12.21	13.18	15.13	18.09	22.47

Source: Johnson (forthcoming).

Table A.4 Average rural and urban marketing costs used in model, by geopolitical zone, Naira/mt

	Standard		Premium	
Zone	Rural	Urban	Rural	Urban
Rural				
North Central	10.8	14.4	17.4	21.6
North East	14.7	19.5	23.6	29.3
North West	7.9	10.5	12.8	15.8
South East	9.1	12.1	14.6	18.2
South South	10.9	14.5	17.5	21.7
South West	9.4	12.6	15.2	18.9
Urban				
North Central	14.4	10.8	21.6	7.9
North East	19.5	14.7	29.3	10.7
North West	10.5	7.9	15.8	5.8
South East	12.1	9.1	18.2	6.7
South South	14.5	10.9	21.7	8.0
South West	12.6	9.4	18.9	6.9

Source: Calculated by authors.

Notes: These were purposefully kept low due to lack of sufficient data. They are calculated based on distances between state capitals (from Johnson, forthcoming) to serve as weights, and unit costs of 0.75 Naira/kg (rural-to-rural marketing), 0.55 (urban-to-urban), 1.00 (rural-to-urban), and 1.50 (urban-to-rural).

Table A.5 Baseline local production of standard and premium rice varieties in Nigeria, by state, 2009, thousand mt

State	Standard (local)		Premium (local)		State	Standard (local)		Premium (local)	
and zone	Rural	Urban	Rural	Urban	and zone	Rural	Urban	Rural	Urban
North Central					South East				
Benue	217.2	0.0	0.0	115.2	Abia	2.7	0.0	0.0	0.0
FCT-Abuja	4.4	0.0	0.0	0.0	Anambra	1.9	0.0	0.0	0.0
Kogi	75.3	0.0	0.0	0.0	Ebonyi	183.6	0.0	0.0	115.2
Kwara	49.7	0.0	0.0	0.0	Enugu	55.5	0.0	0.0	57.6
Nasarawa	71.0	0.0	0.0	57.6	Imo	0.6	0.0	0.0	0.0
Niger	401.8	0.0	0.0	0.0	South				
Plateau	78.7	0.0	0.0	0.0	Akwa-Ibom	1.4	0.0	0.0	0.0
North East					Bayelsa	0.3	0.0	0.0	0.0
Adamawa	156.1	0.0	0.0	0.0	Cross River	1.8	0.0	0.0	0.0
Bauchi	33.0	0.0	0.0	0.0	Delta	1.3	0.0	0.0	0.0
Borno	185.3	0.0	0.0	0.0	Edo	11.7	0.0	0.0	0.0
Gombe	66.6	0.0	0.0	0.0	Rivers	0.0	0.0	0.0	0.0
Taraba	176.9	0.0	0.0	0.0	South West				
Yobe	53.5	0.0	0.0	0.0	Ekiti	36.0	0.0	0.0	0.0
North West					Lagos	4.6	0.0	0.0	0.0
Jigawa	41.6	0.0	0.0	0.0	Ogun	6.0	0.0	0.0	57.6
Kaduna	454.1	0.0	0.0	57.6	Ondo	26.3	0.0	0.0	0.0
Kano	262.8	0.0	0.0	230.4	Osun	1.7	0.0	0.0	0.0
Katsina	21.2	0.0	0.0	0.0	Oyo	0.1	0.0	0.0	0.0
Kebbi	52.9	0.0	0.0	57.6					
Sokoto	45.8	0.0	0.0	0.0					
Zamfara	24.8	0.0	0.0	0.0					

Source: NAERLS (2009).
Notes: Standard (local) rice is produced in rural areas while premium (industrial milling) rice is produced in urban centers only.

REFERENCES

Anderson, K. 2009. *Distortions to Agricultural Incentives: A Global Perspective, 1955–2007*. Washington, DC: World Bank.

Arndt, C., and R. Schiller. 2000. “Grain Transport and Rural Credit in Mozambique: Solving the Space-Time Problem.” *Agricultural Economics* 25:59–70.

Barrett, C. B., and P. A. Dorosh. 1996. “Farmers’ Welfare and Changing Food Prices: Nonparametric Evidence from Rice In Madagascar.” *American Journal of Agricultural Economics* 78:656–669.

Diao, X., M. Johnson, and H. Takeshima. Forthcoming. “Economywide Effects and Implications of Alternative Policies.” In Transforming the Nigerian Rice Economy, edited by K. Gyimah-Brempong, M. Johnson, and H. Takeshima. Philadelphia: University of Pennsylvania Press.

Dorosh, P., and M. Malek. Forthcoming. “Rice Imports, Prices and Challenges for Trade Policy.” In Transforming the Nigerian Rice Economy, edited by K. Gyimah-Brempong, M. Johnson, and H. Takeshima. Philadelphia: University of Pennsylvania Press.

FAO (Food and Agriculture Organization of the United Nations). 2014. FAOSTAT database. Accessed November 13, 2014. http://faostat.fao.org.

Gyimah-Brempong, K., M. Johnson, and H. Takeshima, eds. Forthcoming. Transforming the Nigerian Rice Economy. Philadelphia: University of Pennsylvania Press.

Gyimah-Brempong, K., and O. Kuku. Forthcoming. “Evolution of Consumption and Demand Patterns.” In Transforming the Nigerian Rice Economy, edited by K. Gyimah-Brempong, M. Johnson, and H. Takeshima. Philadelphia: University of Pennsylvania Press.

Harker, P. T. 1986. “Alternative Models of Spatial Competition.” *Operations Research* 34 (3): 410–425.

Jabara, C. L., and R. L. Thompson. 1982. “The Optimal Tariff for a Small Country under International Price Uncertainty.” *Oxford Economic Papers* 34 (2): 326–331.

Johnson, M. Forthcoming. “Policy Options for Modernizing the Milling Sector.” In *Transforming the Nigerian Rice Economy*, edited by K. Gyimah-Brempong, M. Johnson, and H. Takeshima. Philadelphia: University of Pennsylvania Press.

Krueger, A. 1997. “Trade Policy and Economic Development: How We Learn.” *The American Economic Review* 87 (1): 1–22.

Minot, N., and F. Goletti. 1998. “Export Liberalization and Household Welfare: The Case of Rice in Vietnam.” *American Journal of Agricultural Economics* 80:738–749.

Nigeria, NAERLS (National Agricultural Extension and Research Liaison Services). 2009. “Crops data from Annual Agricultural Survey Report of the 2009 Wet Season.” Abuja, Nigeria: Federal Ministry of Agriculture and Rural Development.

Nigeria, NBS (National Bureau of Statistics). 2012. “Farmgate Prices of Agricultural Products.” Accessed on May 1, 2015. www.nigerianstat.gov.ng/pages/download/143.

Rahji, M .A. Y., and M. O. Adewumi. 2008. “Market Supply Response and Demand for Local Rice in Nigeria: Implications for Self-Sufficiency Policy.” *Journal of Central European Agriculture* 9 (3): 567–574.

Rutherford, T. 1995. “Extension of GAMS for Complementarity Problems Arising in Applied Economic Analysis.” *Journal of Economic Dynamics and Control* 19:1299–1324.

Takayama, T., and H. Hashimbo. 1984. *A Comparative Study of Linear Complementarity Programming Models and Linear Programming Models in Multi-regional Investment Analysis.* Division Working Papers DWC 8401. Washington, DC: World Bank.

Takayama, T., and G. G. Judge. 1964. “Equilibrium among Spatially Separated Markets: A Reformulation.” *Econometrica* 32 (4): 510–524.

Takeshima, H., and O. Bakare. Forthcoming. "Production Systems: Biophysical and Economic Environment, and Constraints." In Transforming the Nigerian Rice Economy, edited by K. Gyimah-Brempong, M. Johnson, and H. Takeshima. Philadelphia: University of Pennsylvania Press.

UN Statistics Division. 2012. United Nations Commodity Trade Statistics database (COMTRADE). Accessed on June 11, 2015. www.comtrade.un.org.

USDA (United States Department of Agriculture). 2013. "Production, Supply and Distribution Online." Foreign Agricultural Services, USDA. Accessed on June 11, 2015. www.fas.usda.gov/psdonline/.

RECENT IFPRI DISCUSSION PAPERS

For earlier discussion papers, please go to www.ifpri.org/pubs/pubs.htm#dp.
All discussion papers can be downloaded free of charge.

1492. *Smallholders and land tenure in Ghana: Aligning context, empirics, and policy.* Isabel Lambrecht and Sarah Asare, 2015.

1491. *Returns to agricultural public spending in Africa South of the Sahara*. Samuel Benin, 2015.

1490. *Lost in translation: The Fractured conversation about trade and food security*. Eugenio Díaz-Bonilla, 2015.

1489. G*ender roles and food safety in 20 informal livestock and fish value chains.* Delia Grace, Kristina Roesel, Erastus Kang'ethe, Bassirou Bonfoh, and Sophie Theis, 2015.

1488. *Farm household typologies and mechanization patterns in Nepal Terai: Descriptive analysis of the Nepal Living Standards Survey*. Hiroyuki Takeshima, Rajendra Prasad Adhikari, Mahendra Nath Poudel, and Anjani Kumar, 2015.

1487. *Public-private partnerships and the reduction of undernutrition in developing countries.* John Hoddinott, Stuart Gillespie, and Sivan Yosef, 2015.

1486. *How does women's time in reproductive work and agriculture affect maternal and child nutrition?: Evidence from Bangladesh, Cambodia, Ghana, Mozambique, and Nepal.* Hitomi Komatsu, Hazel Jean L. Malapit, and Sophie Theis, 2015.

1485. *US maize data reveals adaptation to heat and water stress*. Timothy S. Thomas, 2015.

1484. *Customary tenure and innovative measures of safeguarding land rights in Africa: The community land initiative (iniciativa de terras comunitárias) in Mozambique*. Hosaena Ghebru, Raul Pitoro, and Sileshi Woldeyohannes, 2015.

1483. *The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT): Model description for version 3*. Sherman Robinson, Daniel Mason-D'Croz, Shahnila Islam, Timothy B. Sulser, Richard Robertson, Tingju Zhu, Arthur Gueneau, Gauthier Pitois, and Mark Rosegrant, 2015.

1482. *Enhancing food security in South Sudan: The role of public food stocks and cereal imports.* Paul A. Dorosh, Shahidur Rashid, Abigail Childs, and Joanna van Asselt, 2015.

1481. *Gender, headship, and the life cycle: Landownership in four Asian countries.* Kathryn Sproule, Caitlin Kieran, Agnes Quisumbing, and Cheryl Doss, 2015.

1480. *The food-energy-water security nexus: Definitions, policies, and methods in an application to Malawi and Mozambique.* Thea Nielsen, Franziska Schunemann, Emily McNulty, Manfred Zeller, Ephraim Nkonya, Edward Kato, Stefan Meyer, Weston Anderson, Tingju Zhu, Antonio Queface, and Lawrence Mapemba, 2015.

1479. *The making of public investments: Champions, coordination, and characteristics of nutrition interventions*, Tewodaj Mogues and Lucy Billings, 2015.

1478. *The dynamics of smallholder marketing behavior: Explorations using Ugandan and Mozambican panel data.* Bjorn Van Campenhout, 2015.

1477. *Adjusting to external shocks in small open economies: The case of Honduras.* Samuel Morley and Valeria Piñeiro, 2015.

1476. *Drivers of growth in agricultural returns to scale: The hiring in of tractor services in the Terai of Nepal.* Hiroyuki Takeshima, 2015.

1475. *The contribution of increased equity to the estimated social benefits from a transfer program: An illustration from PROGRESA.* Harold Alderman, Jere R. Behrman, and Afia Tasneem, 2015.

1474. *Reconstructing public expenditure data: Use of classification systems to better measure public spending in agriculture — A Mozambique case study*. Tewodaj Mogues, Leonardo Caceres, Francisco A. Fernandez, and Mariam B. Umarji, 2015.

1473. *Agricultural insurance and the World Trade Organization*. Joseph W. Glauber, 2015.

1472. *Grain price and volatility transmission from international to domestic markets in developing countries.* Francisco Ceballos, Manuel A. Hernandez, Nicholas Minot, and Miguel Robles, 2015.

1471. *Policy changes in times of crisis: Evidence from the Arab Spatial Policy Analyzer.* Jacopo Bordignon and Clemens Breisinger, 2015.

1470. *Gender empowerment gaps in agriculture and children's well-being in Bangladesh.* Hazel Jean L. Malapit, Esha Sraboni, Agnes R. Quisumbing, and Akhter Ahmed, 2015.

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

www.ifpri.org

IFPRI HEADQUARTERS

2033 K Street, NW
Washington, DC 20006-1002 USA
Tel.: +1-202-862-5600
Fax: +1-202-467-4439
Email: ifpri@cgiar.org