DEMAND AND SUPPLY RESPONSES OF AFRICA'S FOOD SYSTEMS TRANSFORMATION: EVIDENCE FROM CONSUMPTION PATTERNS AND TECHNOLOGY ADOPTION IN NIGERIA

By

Charuta M. Parkhi

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ABSTRACT

In the last few decades, Africa's food systems have transformed considerably due to rapid rates of urbanization and income growth. Consistent with Bennett's law, the share of food budgets on starchy staples has declined and has been replaced by other nutrient-dense foods such as animal proteins and horticultural produce. Such changing demand, along with increased dependence on markets, has also triggered a significant supply response in various aspects, including technology adoption.

This dissertation explores key issues related to consumption and production of nutrient-dense foods using evidence from Nigeria. The first chapter conducts disaggregated demand analysis of fruit and vegetable (FV) consumption, with a goal to understand evolving consumption patterns. International debates focusing on incredibly low FV consumption often discuss supply-side concerns such as availability and affordability. However, demand-related issues linked to consumer preferences have remained largely unexplored. Using a detailed decade-long panel dataset and demand estimation techniques, this study assesses heterogeneity in consumption patterns (trends and elasticities) for different items across regions and income groups over time. We also differentiate between fresh and processed items as well as domestic vs imported items. This analysis reveals that vegetable consumption is much lower than the recommended levels and is not likely to increase even with increasing incomes given consumers preference for "tastier" foods such as animal proteins. Further, detailed examination of different items uncovers interesting behavioral patterns and demonstrates how efforts could be made to increase FV consumption and support producers with implications for overall malnutrition and food insecurity.

Next, the second chapter investigates consumer demand for animal proteins using panel data and various demand estimation techniques. Dramatic increases in meat production as a response to increasing demand have already raised concerns related to sustainability. As demand continues to rise, a thorough assessment of consumer preferences for different sources of animal proteins over varying socio-economic and agroecological regions is crucial for both sustainable production and effective functioning of markets. The results suggest that animal-protein demand will continue to increase with rising incomes and that seafood and beef are the most popular forms of animal proteins. While there are significant differences in preferences across regions and income groups, it is consistently noted that poultry meat and eggs are rapidly gaining

popularity. As poultry production is less-resource intensive with shorter production cycles, strengthening poultry value chains could play an important role in sustainably meeting the rising demand for animal proteins in Nigeria.

Finally, the third chapter examines technology adoption among poultry farmers with implications for food safety. Poultry farmers across the world have been using antibiotics for both therapeutic and non-therapeutic purposes. In fact, their excessive use has already developed concerns related to the emergence of antimicrobial resistant strains of bacteria. In Africa, while poultry production has already progressed towards greater intensification, there is still a common perception that it primarily occurs in backyard settings with limited input utilization. Therefore, small farms remain largely ignored from the discussions related to the responsible use of antibiotics. This study assesses heterogeneity in antibiotics use over farm sizes and regions. The results indicate that antibiotic use, especially for non-therapeutic purposes, is prevalent among farms of all sizes across regions. This debunks yet another myth that poultry practices are largely traditional with little fear of antimicrobial resistance. While large farms are more likely to adopt antibiotics, its indiscriminate use is more evident among small farms and those in less developed areas. Furthermore, these findings reveal that information dissemination through social networks and extension services plays a crucial rule in the efficient use of antibiotics, particularly in the absence of regulation in developing countries like Nigeria.

In essence, the findings of this dissertation underscore the need for a coordinated and holistic approach to address the complex challenges facing food systems in Africa, from promoting consumption of vegetables to diversifying sources of animal proteins and adopting responsible technologies. Failure to address these challenges risks perpetuating food insecurity, malnutrition, and environmental degradation, with far-reaching consequences for the well-being and livelihoods of millions of people across the continent.

Dedicated to the memory of Baba, my father, who was the guiding light in my academic life. You were overjoyed when I embarked on this journey and would have been the happiest person to see me reach this milestone.

Until we meet again,

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CHAPTER 1: HETEROGENEOUS CONSUMPTION PATTERNS OF FRUITS AND VEGETABLE IN NIGERIA: A PANEL DATA ANALYSIS

1.1. Introduction

Globally food systems are rapidly transforming due to increased incomes and urbanization. As predicted by Bennett's law, rising incomes lead to a movement of food budget shares away from starchy staples to more nutrient-dense non-starchy foods. Yet, the double burden of malnutrition (undernutrition and overnutrition) continues to remain a challenge in low and middle-income countries (Headey and Alderman, 2019; Hirvonen et al., 2020, Ruel et al., 2008). Undernutrition is associated with insufficient consumption of non-starchy foods such as fruits and vegetables, pulses, and animal proteins. Overnutrition, on the other hand, is caused due to excessive consumption of oil, sugar, and other ultra-processed foods. Both these dimensions of malnutrition often co-exist along with a third important aspect namely micronutrient deficiencies or "hidden hunger" (Gomez et al., 2013).

Fruits and vegetables (FV), rich in micronutrients and low in calories, can play an important role in alleviating the burden of malnutrition. In fact, as expected, the share of food budgets spent on FV have increased with increasing incomes (Tschirley et al., 2015). Among developing countries, FV consumption in Asia increased rapidly after 1980s (Pingali, 2007) and constituted about 15% of the food budget in 2010 (Reardon, 2014). A similar increase in FV budgets in Africa took place recently almost two decades after the Asian wave (Smale et al., 2020). However, despite the apparent increase in the importance of FV in diets, average global daily consumption of FV is still incredibly low at only 190g per capita (much lower than the recommended levels)[1] and even lower at 50g per capita in developing regions. Thus, the consumption of vitamin-rich FV is a major issue in the food security debates of developing countries, including in Sub-Saharan Africa in general and Nigeria in particular. There is much evidence of persistent undernutrition associated with, among other factors, inadequate consumption of non-starchy-staples such as FV (e.g., see Reardon et al., 2021 and Popkin and Reardon, 2018).

Several reasons for low FV consumption have been documented in the international debate. First, there is concern that FV cost consumers too much due to inadequate supply (Anderson & Birner, 2020; Miller et al., 2016; Vermeulen et al., 2020). Second, there is constrained access of FV to poor regions and poor households in developing countries. There appears to be an

[1] As per the Healthy Diet Basket that provides daily recommended quantities for different food groups, daily recommended levels for vegetables are 270-400 grams per capita and that for fruits are 230-300 grams per capita.

assumption that it is mainly the urban middle class that relies on and gets FV. Third, there is concern that the above situation is frozen, not improving, not transforming, that farmers are not growing nearly enough FV, and supply chains selling them to consumers are missing (Liverpool-Tasie et al. 2021). All these reasons above suggest that FV consumption is highly dependent on food purchases and thus supply chains are crucial for the efficient functioning of markets.

On the other hand, some demand studies focusing on vegetable as a food group found lower expenditure elasticity for the vegetable food group while high elasticities were noted for animal-proteins and fruit food groups (eg. McCullough et al., 2022). This means that even with rising incomes demand for vegetables continues to remain low although consumption levels are way below the recommended quantities. These findings belie the reigning view that affordability and availability are the main reasons for low levels of consumption and bring forth other demand related issues such as consumer preferences.

Therefore, it is necessary to understand consumer demand and evolving consumption patterns. A systematic disaggregated demand analysis of different types of vegetables and fruits is important to understand consumer preferences. Such information might provide insights for finding ways to promote and encourage FV consumption. Additionally, a deep knowledge of consumer preferences may also create demand-driven value chains which may in turn improve affordability and availability of FV. This paper aims to contributing to this goal by conducting a disaggregated demand analysis for different types of FV using Nigeria as a case study.

Nigeria's situation is intriguing due to its massive population and the highest GDP in Africa. The increase in income and urbanization has led to a surge in food demand, with a shift in dietary preferences. Bennett's law holds true, as the expenditure on starchy staples has decreased, making way for animal proteins and FV consumption (Tschirley et al., 2015; Muyanga et al., 2019). Based on the expenditure elasticities of these food groups, we observe a substantial increase in spending on animal proteins and relatively low spending on FV, which poses a challenge for increasing FV consumption in Nigeria (Zhou and Staatz, 2016). As such, it is crucial to delve deeper into consumer demand and explore strategies to boost FV consumption.

Our research addresses the gaps in current literature by investigating the consumption patterns, food expenditure, and price elasticities of fruits and vegetables in Nigeria. We utilized a nationally representative panel survey covering a decade to account for possible variations in employment, market access, lifestyle, and preferences by analyzing data from both urban and rural areas. We also segmented our analysis into the less developed North and the more developed South to gain insights into the differences in FV demand and consumption across regions with different development and agroecology. Our use of panel data enables us to capture changes in FV consumption over time while controlling for time-invariant variables.

This study contributes to the literature in several ways. First, we add to the limited literature of horticulture demand by estimating demand for different products within FV group. Second, in the context of Africa, our study demand for different FV in urban and rural regions. Third, we also analyze the impact of heterogeneity in demand for FV in the richer South and the poorer North. Fourth, using tomatoes as an example we distinguish between processed and fresh forms of vegetables to analyze the heterogeneity in consumption patterns. Tomato also allows us to distinguish between consumption patterns for domestic and imported products. Fifth, using panel data is an important contribution which allows us to capture how FV consumption has changed over time by allowing to control for time invariant factors.

The paper proceeds as follows. In Section 1.2 we discuss the data used. Section 1.3 presents a description of FV consumption patterns across Nigeria over time. Section 1.4 describes the methodological approach used to estimate consumer demand. Section 1.5 presents the findings and section 1.6 formulates insights based on our results. Section 1.7 concludes.

1.2. Data

The data utilized in our study focuses on household characteristics and food consumption, which was collected through the Nigeria Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA) program under the auspices of the World Bank. This particular survey was conducted on a national scale, covering both urban and rural areas of six geopolitical zones in Nigeria. This wide coverage provides a valuable glimpse into the agroecology and demographic differences that exist between the richer South and the poorer North of Nigeria. We have relied on four rounds of data collected in the years 2010/11, 2011/12, 2015/16, and 2018/19. In each of these rounds, approximately 5000 distinct households were surveyed twice a year, once during the post-planting season and again during the post-harvest season. This strategy was used to capture any seasonal variations in consumption patterns. To create a panel dataset, we have used the first three rounds of data as they include the same households that were interviewed in each round of data collection.[2]

The household food consumption module collects quantities of various food items consumed in the preceding 7 days of the interview. We aggregate the food items into food-at-home groups including different vegetables and fruits and other food groups. These categories include FV items - okra, onion, pepper, fresh tomato, tomato paste, green leafy vegetables (GLVs), eggplant, potato, fruits, other vegetables (canned vegetables etc) - and other food groups namely cereals, tubers, pulses, oils, animal proteins, dairy, and other foods.

Our analysis includes all products consumed by households, whether purchased, home-produced, or received as gifts. Due to the lack of item-level prices in the data, we calculate prices by dividing the total expenditure on purchased items by the quantity purchased. However, when food items are not purchased, we impute their unit prices using median unit values at the item, unit, and location level, beginning with the most granular location specification (EA). To ensure consistency, we cap prices that exceed the median at the median price for the corresponding item, unit, and location. We then calculate the total value of food items consumed by households by multiplying the quantity consumed from all sources by the calculated price. To remove outliers, we use winsorization to cap per capita quantities of each item at the 99th percentile. Finally, we convert nominal prices and expenditure values into real values using Nigeria's consumer price index (CPI) for each survey year, with 2010 as the base year.

We use an income classification that divides the households into three groups based on total of food and non-food purchases (TE) as a proxy for income. The poorest group (Tercile 1) includes households with total per capita daily expenditure of less than 1.9 constant dollars in purchasing power parity (PPP) per person per day in 2011. The middle group (Tercile 2) includes households with daily per capita PPP of greater than \$1.9 but less than \$4. Finally, the richest group (Tercile 3) includes households with daily per capita PPP greater than \$4.

[2] Our descriptive statistics are presented as aggregate of both post planting and post-harvest. This increases the consumption values for different food items significantly compared to just using the share who consumed in either period separately. This might be because of seasonal accessibility and affordability constraints of a household. Thus, measuring yearly consumption allows us to get a better sense in terms of desirability of different items. For elasticity estimations we exploit the panel structure of the data and create a panel of 6 time periods (2 rounds in each of the 3 waves).

1.3. Descriptive statistics and consumption patterns

Table 1.1 shows real prices for different FV items and other food groups. We will refer to this table throughout our analysis.

Table 1.2 shows consumption of fruit and vegetable separately and as food group (FV) over time in the North and South of Nigeria. Almost all households consistently consumed at least some form of vegetable in a typical week in each time period in both the regions. The share of fruit-consuming households, however, almost doubled from 32% to 63% in the North over the last decade. Similarly, in the South, the share of fruit-consuming households increased from 58% to 83% during this time.

Further, the share of food budgets spent on FV is comparable with other African countries at 13% in the North and 16% in the South as per the 2018/19 data with a significantly higher share spent on vegetables than fruits. However, while food budgets spent on vegetables remained constant over time in both regions, that for fruits doubled from 1% to 2% in the North and from 2% to 4% in the South.

In terms of per capita daily quantities, as per the 2010/12 data, FV consumption was higher at 148 grams in the North than 127 grams in the South. However, over the last decade FV consumption in the North first declined to 102 grams in 2015/16 and then increased again to 148 grams in 2018/19. While vegetable consumption more than halved in the North (from 129 grams to 77 grams), it was compensated by the increase in fruit consumption by more than 4 times from 19 grams to 71 grams. In the South, however, consumption of FV steadily increased and almost doubled from 127 grams to 225 grams over the last decade. This increase was predominantly driven by the increase in fruit consumption by 3 times (from 38 grams to 110 grams) while vegetable consumption increased slightly from 89 grams to 114 grams.

Overall, this suggests that while fruit consumption increased dramatically in both North and South over the last decade, vegetable consumption declined in the North and increased only marginally in the South. Yet, fruit and vegetable consumption levels are much below the daily recommended levels of 270-400 grams/capita for vegetables and 230-300 grams/capita for fruits.

Table 1.3 presents disaggregated share of households consuming for different types of FV across time and over regions. Some interesting observations emerge. First, onion is the most popular vegetable consumed by almost all households in both North and South (98% households in the North and 99% in the South) as per 2018/19 survey. Further, peppers are another important

FV item with 70% households in the North and 92% in the South consuming them in a week. Tomato is also consumed by a large share of households in both regions. While fresh tomato is popular in both North and South (consumed by 80% and 82% households respectively), tomato paste is consumed by 58% of the households in the South and by only 8% in the North. Such high shares of households consuming both fresh tomato and tomato paste in the South suggest that processed tomato is an important product by itself, and not just a substitute for fresh tomato.

Moreover, okra (a traditional vegetable with origin in Africa) is still a popular item with the share of households being 74% and 66% in the North and South respectively. GLVs are consumed by about 31% of the households in the North and 52% in the South. On the contrary, the share of consumers of African eggplant are very low at just 10% in the North and 19% in the South despite being a traditional vegetable. Potato, introduced by Christian missionaries in Nigeria in the 19th century and produced in the Northern region, remains a less popular item. In the North only 5% consumers eat potato in a week while in the South this number is just 2%. Interestingly, fruits (mainly bananas and oranges) are consumed by a large share of households, 63% in the North and 83% in the South.

Second, there have been notable shifts in the consumption patterns of vegetables and fruits in the North region of the country. Onion consumption has steadily increased (albeit from a high base), with 98% of households consuming it in 2018/19, compared to 91% in 2010/11. In contrast, the share of households consuming pepper in the same region has declined from 82% to 70% over the same period. Tomato consumption has remained relatively stable between 2010/11 and 2018/19. Interestingly, there has been a significant growth in the share of households consuming green leafy vegetables (GLVs) and fruits. Though the consumer share for GLVs plunged from 14% to 6% between 2010/11 and 2015/16, it increased considerably to 31% in 2018/19. Similarly, fruit consumption has nearly doubled, with 63% of households consuming it in 2018/19 compared to 32% in 2010/11. This increase in fruit consumption was predominantly driven by the increase in orange consumption over the last decade.

Third, in the South, the share of households increased or remained nearly constant for popular vegetables such as onion (from 89% to 99%), pepper (from 90% to 92%), fresh tomato (77% to 82%), tomato paste (52% to 58%), and okra (48% to 66%). Even the share of households for less popular vegetables increased - potato (1% to 2%), and eggplant (about 10%) - over the decade. Similar to the North, a considerable rise in the share of consumers was noted for fruits and

GLVs. The consumer share of fruits increased from 53% in 2010/11 to 83% in 2018/19 (driven by bananas and oranges) and that for GLVs increased over 5-fold from 10% to 52% over the same period.

Fourth, we note some interesting similarities and differences between the urban and rural areas of the poorer North and the more affluent South. Onion consumption is ubiquitously high across urban and rural areas of both regions with almost all households consuming onions in the survey week. Further, as expected, the consumer share for fresh tomato is higher in the urban areas than in rural areas of both North and South (about 95% in urban areas of both regions and 75% in rural areas). On the contrary, while tomato paste has higher consumer share in urban areas of the North (12% in urban areas vs 7% in rural areas), in the South the consumer share is higher in rural areas (61% in rural areas vs 54% in urban areas).

Further, while pepper consumption in the urban areas is higher than in rural areas in the North, more than 90% South Nigerians in both urban and rural areas consume pepper in a given week as seen 2018/19 survey data. For fruits, the disparity between urban and rural is much higher (78% in urban areas vs 59% in rural areas) in the North than that in the South (86% in urban areas vs 80% in rural areas). Also, it is interesting to note that, over the last decade, the most rapid expansion occurred in fruit consumption in rural areas in both North and South. In the rural North, the share of fruit consumers more than doubled from 27% to 59% while in the rural South it increased by 0.5 times from 58% to 80%.

Table 1.4 describes the share of households by per capita income groups over regions. Overall FV items are consumed by almost all households in all income groups across regions. We notice heterogeneity in consumption of different FV items across income groups.

First, in both North and South, onions are consumed by almost all households (more than 98%) belonging to all income groups. Among other popular FV items, as expected, the consumer shares are higher among the richest group as compared to the poorest group with stark difference in the consumption of peppers and fruits in the North. In the North, 61% of the poorest households and 91% of the richest consumed peppers. Similarly only 54% of the poorest consumed fruits while 84% of the richest did so.

Second, despite the popularity of “westernized” vegetables (onions, tomato, peppers), okra is consumption is still high among both rich and poor. Okra consumption remains nearly constant

(73% in lowest income tercile and 71% in the richest tercile) in the North, it is slightly regressive in the South (75% in the lowest tercile and 61% in the richest).

Third, in the North, the consumer share for GLVs in the poorest tercile is 26% while that in the richest tercile is about 44% in 2018/19. In the South, however, these numbers are nearly constant at about 52%. This might be due to abundance of GLVs in the South which is conducive to GLV production.

Fourth, although overall consumption is low for potato and eggplant, our data suggests that consumption of these items increases sharply with income. In the North, consumer share of potato in the poorest tercile is only 2% while that in the richest tercile is 10 times higher at 21%. In the South, consumer share of potato in the richest tercile is three times higher than the poorest tercile, albeit already low levels (3% and 1% respectively). Also, the share of eggplant consumers in the richest tercile is 2.5 and 2 times higher than that in the lowest tercile in the North (7% among the poorest and 18% among the richest) and South (12% and 24% among the poorest and the richest) respectively.

Fifth, among the poorest group, fruit consumers more than tripled (from 14% to 54%) in the North and more than doubled in the South (from 33% to 72%) between 2010/11 and 2018/19. Similarly, GLV consumption in the lowest tercile tripled (9% to 27%) in the North and increased 6 times from (9% to 54%) over the same time period. While okra consumption among the poorest remained consistently high at about 72% in the North, it increased from 43% to 75% in the South, again suggesting the importance of the traditional vegetable even in the affluent South.

Table 1.5 shows per capital annual consumption (in kg) for different types of FV items across regions over time. First, per capita annual FV consumption is higher in the South (about 82 kg) as compared to the North (54 kg) as per the 2018/19 data. A deeper dive into the disaggregated consumption shows that per capita consumption of all FV items is higher in the South than in the North except for the not-so-important potato. Per capita annual consumption of potato in the South is only 0.3 kg, and in the North it is higher at 1.3 kg. While a clear luxury in the North, its tiny consumption in the South could be because of competing roots and tubers on the one hand and other vegetables dominance in dishes.

Even among important vegetables, onion consumption is slightly higher at about 10 kg in the South as compared to 8.5 kg in the North. Per capita annual fresh tomato consumption is higher in the South (10.7 kg) than in the North (7.7 kg), thus reiterating the importance of fast-moving supply chains transporting perishables like tomato from the production region in the North to the South. Further, fruit consumption in the North is at 40kg per capita annually while it is 26 kg per capita in the South.

Second, in the North, overall annual per capita consumption of FV remained nearly constant at about 54kg. This is indeed concerning given the already low levels of FV consumption in Nigeria. Further disaggregated analysis shows that per capita consumption of popular vegetables in fact declined and, in many cases, drastically. For example, while per capita annual onion consumption declined slightly from about 10 kg to 8.5 kg over the decade, it nearly reduced by 50% for fresh tomato (16.2 kg to 7.7 kg) and pepper (6.1 kg to 3.6 kg) over the decade. Even okra saw a decline in consumption of about 70% from about 8 kg to 2.5 kg during this period. Such decline in per capita consumption despite decreasing real prices is worrisome and implies either low preference for these items or lack of competitive markets. Even the per capita consumption of less important vegetables such as eggplant and potato, already consumed in low quantities, nearly halved between 2010/11 and 2018/19.

On the other hand, GLV consumption also increased by 3 times from 1.1 kg to 3.3 kg per person per year. Further, the good news is that fruit consumption soared by 4 times from 7 kg per capita per year to about 26 kg. These results show that decline in vegetable consumption was compensated for by the increase in fruit consumption, keeping overall FV consumption almost same over the decade.[3]

Third, in the South, unlike the North overall per capita annual FV consumption increased from about 33 kg to 42 kg between 2010/11 and 2018/19. In fact per capita consumption of onion almost doubled from about 5 kg to 10kg annually. Even pepper consumption increased by 21% from about 6 kg to 7.5 kg while tomato consumption remained constant at nearly 11kg. Potato consumption, albeit very low, remained nearly constant at 0.2 kg per person per year and quantity of eggplant consumed increased negligibly from 1.1 kg to 1.7 kg. Tomato paste[4], an important product in the South, saw a decline in consumption by more than 50% from 4.1 kg to 1.5 kg. Such decline might be due to a severe pest attack in 2015 which caused a dip in Nigeria's tomato production and the consequent increased reliance on imported tomato paste. This is also

[3] Consumption of GLVs remained incredibly low until 2015/16.
[4] 1 kg of tomato paste equals 5.6 kg of fresh tomato.

evident from increase in real price of tomato paste between 2010/11 and 2018/19 as seen in Table 1.1. Similar to the North, per capita annual fruit consumption rose by 3 times from about 13.8 kg to 40.3 kg while that of GLVs increased by 6 times from 0.7 kg to 6.5 kg.

Fourth, comparing urban and rural areas of North and South shows that the disparity between areas is higher in the poorer North than in the richer South. In the North, overall FV consumption is 1.5 times in urban areas than in rural areas. For all FV, except okra and potato which are consumed in similar quantities, per capita consumption in the urban North is higher than in the rural North.

In the South, there is no significant difference between overall per capita annual FV consumption in urban areas (85 kg) and rural areas (80 kg). In fact, per capita consumption of okra (2.8 kg in urban vs 3.7 kg in rural), tomato paste (1.3 kg in urban vs 1.6 kg in rural), and GLVs (4.9 kg in urban and 7.6 kg in rural) is higher in the rural areas of the South. We suspect that okra and GLVs being traditional vegetables (requiring higher preparation times and not so versatile) are consumed in higher quantities in rural areas having slow-paced lifestyles. Higher quantities of tomato paste in the rural South might be due to its dependence on the North for the supply of fresh tomato. Fruit and fresh tomato consumption, is however, higher in urban areas.

Table 1.6 shows per capital annual consumption (in kg) for different kinds of FV items over time and regions across income levels and reveals three striking points.

First, comparing per capita consumption of all FV together by terciles in North and South suggests that there does not seem to be much disparity between the two regions. While the poorest in the North consumed about 33.1 kg FV items/ person annually, an average South Nigerian in the same income group consumed about 37.2 kg. In the richest income group, in fact, the richest group in the North consumed higher per capita quantity of FV (129.2 kg) as compared to those in the South (117.8 kg). However, it is important to keep in mind that, in the North, only 9% of the survey households belong to the richest tercile while in the South about 33% households belong this income tercile. Similarly, about 56% of the Northern households belong to the poorest tercile group and only 16% of the Southern households belong to the poorest category. This suggests that although consumption levels do not seem to be very different, low consumption is more widespread in the North than in the South. The higher consumption among the richest in the North as compared to those in the South may be explained by higher production of most FV items in the North giving rich Northerners higher and easier access to FV.

Second, as expected per capita consumption of all FV items increases with income, except for the ‘other vegetables’ category having insignificant levels of consumption (less than 500 grams per person annually) as seen in 2018/19 survey. Even among the most popular vegetables - onions and tomatoes - in both regions, per capita annual consumption in the richest tercile significantly higher than in the poorest tercile. For example, an average North (South) Nigerian in the poorest income group consumed about 6.5 kg (5.5 kg) onion annually while those in the richest group consumed 13.3 kg (12.7 kg). Similarly, the richest in the North consumed about 16.7 kg of tomato, about 4 times higher quantity per capita than the poorest (4.9 kg). Also, in the South, the richest group has per capita annual tomato consumption 14.5 kg which is more than 3 times higher than those in the poorest group (4.5 kg). This is also true among traditional vegetables which are less popular and consumed in lower quantities.

Third, between 2010/11 and 2018/19, the most rapid expansion took place of fruits, especially among the poorest in both regions. In the North, per capita fruit consumption in the poorest income group increased by 12 times from 1.2 kg in 2010/12 to 14.4 kg in 2018/19. In the South, the poorest group in 2018/19 consumed about 5 times higher quantity of fruits per person as compared to those in 2010/11.

Table 1.7 describes budget shares of total FV expenditure on different FV items over regions and over time. First, in the North, onion accounts for the maximum share of FV expenditure at about 27% in 2018/19 followed by fresh tomato (19.2%), okra (16.8%), and pepper (10.4%). Further, 16.4% of FV expenditure is spent on fruits. The FV budget share spent on GLVs is quite low at 5.5% while those for tomato paste, potato, eggplant, and other veg are negligible (below 2%).

Second, in the South, highest consumption shares are noted for onion and tomato at about 17.3% and 17.5% respectively similar to the North. These are followed by pepper at 12% making these top 3 vegetables in the South. Okra budget share in the South is only 7.8% (nearly half of that in the North) although per capita okra consumption is slightly higher in the South than in the North. Fruits are important with South Nigerians spending 23% of FV budgets on them. Moreover, budget shares on tomato paste is at 7.4% and that on GLVs is at 12.2 %, both of which are higher than those in the North.

Third, consistent with the observed expansion of fruits over the decade, the budget share of FV expenditure on fruit increased from 7.4 % to 16.4% in the North and from 15.7% to 23.1% in the South. Even in rural areas of the North, the poorest region of the poorer North, fruit budget shares increased by a multiple of about 3 from 5.8% to 15.2%.

Table 1.8 shows budget shares of total FV expenditure on different FV items over regions and income groups. First, in the North, the FV budget share for onions is high but decreases as income increases with the poorest group spending 30% on this staple vegetable and the richest group about 17.3% as seen in 2018/19 data. On the contrary, the budget shares for other popular vegetables namely tomato and peppers increased slightly or remained nearly constant at approximately 19% and 10% respectively. For the traditional but important okra, the budget shares declined from 19.1% among the poorest to 9.8% among the richest. Further sharpest difference in budget shares was observed for fruits (poorest 13.4 % and richest 26.9%) and GLVs (4.8% among the poorest and 7.4 among the richest) with the richest group spending twice their budgets on these items as compared to the poorest group.

Second, in the South, budget shares for onions decrease with income levels with the poorest spending about 18.5% of their FV budgets and the richest about 15.3%. While the budget shares of pepper remain nearly constant across income groups at about 10%, those for tomato increase slightly from 15.2% to 18.4%. Similar to the North, the richest group spent about 27.7% of their FV budgets on fruits, 1.5 times that of the poorest group (19.1). However, contrary to the North, the budget shares on GLVs is higher at 14% for the poorest group than the 11% for the richest.

Third, even in terms of budget shares, fruit budgets have expanded for the poorest tercile between 2010/11 and 2018/19 in both North and South. In the North, the poorest group spent 3% of their FV budgets on fruits and this number increased by 4.5 times to 13.4% in 2018/19. Similarly in the South, the poorest group spent 9.3% of their budgets on fruits in 2010/11 while the budget share increased by more than twice to 19.1% in 2018/19.

1.4. Econometric methodology

1.4.1. Model

Our elasticity estimations are conducted after creating a balanced panel of 6 rounds (2 rounds from each of 2010/11, 2012/14 and 2015/16 waves of LSMS data). Further, due to low share of consumers for eggplant, potato, and GLVs during this period, we combine these vegetables with the "Other vegetables" category. Finally, our analysis includes 14 FAH categories with 7 FV groups (Fruit, okra, onion, pepper, fresh tomato, tomato paste, other vegetables) and 7 other food groups (Cereals, tubers, pulses, oils, animal proteins, dairy, other foods).

We opted to use the EASI (Exact Affine Stone Index) functional form instead of other commonly used forms such as Almost Ideal Demand System (AIDS) for a few reasons. Firstly, the EASI form allows for flexible Engel curves, which is particularly appropriate for developing countries where income ranges are wide and food expenditure elasticities vary significantly with household income. Secondly, the two-way EASI model is consistent with utility theory and allows Hicksian demand to change with total expenditures by interacting log prices with real expenditures. On the other hand, the AID model only allows for Marshallian demand to change with total expenditures through the income effect in the Slutsky equation.

The two-way approximate EASI demand system is specified as

$$w_{hit}^{*} = \sum_{j=1}^{J} a_{ij} ln\, p_{hjt} + \sum_{j=1}^{J} a_{ijy} y_{ht} ln\, p_{hjt} + \sum_{r=1}^{L} b_{ir} y_{ht}^{r} + \sum_{k=1}^{K} v_{ik}\, z_{hkt} + u_{hit} ----(1)$$

$$h = 1, \dots, H;\ i = 1, \dots, J-1;\ t = 1, 2, 3, 4, 5, 6$$

where w_{hit}^{*} is the latent budget share on the i th category for household h at time t; p_{hjt} is the price index for household h and category j; J is the number of demand categories and equals 14 FAH categories (13 distinct categories and other foods as a numeraire), h denotes the household id and H is the total number of households; y_h is the real total household expenditure; L is the highest degree of total expenditure polynomial to be determined by statistical tests, the $z_{hkt}{}'s$ are K exogenous demand shifters including a constant, the a_{ij}, a_{ijy} , b_{ir}, v_{ik} terms are parameters; u_{hi} is the regression residual. The latent budget share w_{hit}^{*} is associated with observed budget share w_{hit} by $w_{hit} \equiv \max\{0, w_{hit}^{*}\}$, where w_{hit} is calculated as the category expenditure divided by household food expenditure. Following Lewbel and Pendakur (2009), we construct the Stone price-deflated household expenditure $y_{ht} = \ln x_{ht} - \sum_{j=1}^{J} w_{hjt} ln\, p_{hjt}$ where x_{ht} is total nominal household expenditures on food. Further, we also include interactions between real total household food expenditure and log prices thus allowing Hicksian demand to vary with income.

Moreover, we include the vector of demand shifters, z_{hkt}, to control for observed taste heterogeneity among households. This vector, in addition to a constant, includes household head age, household size, and binary variables for education, gender, and areas (urban vs rural). We log and demean continuous variables in our analysis.

In order to account for time-invariant unobserved heterogeneity among households, we utilize the panel structure of our data by employing a correlated random effects specification. Specifically, we follow the approach proposed by Meyerhoefer et al. (2005) and include household-level means of log prices and log price-real expenditure interactions for each food group as additional demand shifters in our model. These effects are incorporated as additional demand shifters in the vector z_{hkt} in equation (1). Thus, our model with household level correlated random effects specification includes additional 28 demand shifters due to inclusion of mean log price and mean log price- real expenditure interactions for 13 food categories and the numeraire (other foods).

1.4.2. Estimation strategy

We use a Tobit model to characterize censoring. We use the Tobit estimator over Shonkwiler and Yen for the following reasons. First, Shonkwiler and Yen develop an improved two-step approach that is general enough to model infrequency of purchase errors as well as other processes generating zero expenditures. However, its application to corner solutions has been criticized as it cannot account for the role of reservation prices (Arndt et al 1999). Second, all methods including Shonkwiler and Yen (1999) and other improvements were designed for cross-sectional data and thus has limited ability to account for preference heterogeneity. Therefore we use the Tobit estimator developed by Perali and Chavas (2000) for cross-sectional data and further extended to panel data by Meyerhoeffer et al (2005) and Kasteridis et al (2011). To estimate the Tobit demand system from equation (1) we use the extended Amemiya's Generalized Least Squares (AGLS) estimator (Zhen et al., 2014).

We address two potential sources of endogeneity. First, ln xh is deflated by a Stone price index and this introduces budget shares into log real total expenditure yh . We correct this endogeneity by instrumenting each household specific Stone price index with a modified index which deflates expenditures by the sample-average budget share for foodgroup j (Zhen et al., 2014; McCullough et al., 2022)

Another concern that needs to be addressed is the endogeneity of prices. This issue can arise when calculating unit item prices from unit values, which could lead to omitted variable bias if unobserved taste preferences drive consumers to substitute a more expensive item with a cheaper one in the same food category. To address this problem, we follow the approach of Zhen et al. (2011) and construct Fisher Ideal Price Indexes at the food group level for each household. This helps to account for potential endogeneity issues and ensure that our price measures are more accurate. The Fisher Ideal Price Index gives a second-order approximation to a linear expenditure function and hence addresses unit value bias due to substitution between items within a foodgroup (Diewert;1976; McCullough 2022). Therefore, the Fisher Price Index for household h and foodgroup j in time period t is given by

$$p_{hjt} = \sqrt{\frac{\sum p_{kh} q_{k0}}{\sum p_{k0} q_{k0}} \frac{\sum p_{kh} q_{kh}}{\sum p_{k0} q_{kh}}} - - - - (2)$$

Where p_{kh} and q_{kh} are unit price and quantity, respectively, of food item k in food group j consumed by household h in time period t; p_{k0} and q_{k0} are base unit price and base quantities respectively, and are calculated as average values for item k across all households in time period t.

It is possible that when prices for certain items are high, consumers may opt for lower quality items instead. This introduces a bias when estimating demand using unit values, as the quality of items is not taken into account (Cox and Wohlgenant 1986; Deaton 1988). Additionally, households with preferences for specific items may engage in price search and obtain lower prices for those items, which also introduces bias. Fisher Price Ideal Indexes don't address these endogeneity issues. To address them, we use instrumental variables for prices. We create price instruments for each price index, p_{hjt}, by calculating the average price index of all households in each round and EA except for the focal household. While the identifying assumption that household-level demand shocks are uncorrelated with those of its neighbors may not always hold, we can use household-level correlated random effects to strengthen this assumption (McCullough, 2022).

Further, as culture and income significantly differ across the North and South Nigeria, the two regions vary on several characteristics including food choices. We exploit this heterogeneity in regions by estimating equation (1) separately for the two regions.

We report median elasticities by region (North vs South), areas (urban vs rural), and income groups (poorest, medium, richest).

1.5. Regression Results

As noted above, we estimate the system of $J-1$ (where J is the number of food groups) Tobit equations separately for the North and the South using the extended AGLS estimator. For both the estimations we determined the optimal order of polynomial on real total food expenditure by sequentially increasing L from 1 to 4 and then testing the joint significance of b_{iL} coefficients by minimum distance. We restrict the value of L to 4 as higher order polynomials could cause multicollinearity. We conduct the test without imposing the conditions of homogeneity and symmetry on the demand system as this would have become a joint test of the coefficients and the restrictions. The null hypothesis for the test is that y_h^L can be excluded from the demand system, and the test statistic is asymptotically distributed as $\chi^2(J-1)$. For the North, when L = 4 the test statistic is 75.51 (with a p-value < 0.00) and thus we fail to reject the null hypothesis that L = 4 can be excluded from the demand system. Similarly, for the South, at L = 4, the test statistic is 40.88 (with a p-value < 0.00) and again we fail to reject the null hypothesis. Thus, for both the models, we conclude that L = 4 is the optimal degree of the polynomial.

Also, we tested for the joint significance of the coefficients on the interaction between log prices and income a_{ijy} without imposing the economic restrictions of symmetry and homogeneity. For both the models, the test statistics (1924.94 and 1174.54 with 156 degrees of freedom) are significant with a p-value less than 0.00. Thus, this underpins our choice of EASI which allows the Hicksian demand to vary with total expenditure.

We report median expenditure elasticities for different food groups and disaggregated FV. Table 1.9 describes expenditure elasticities across two regions by urban vs rural areas. As expected, all FV are normal goods in Nigeria. Several other interesting observations emerge.

First, in the North, onion and okra are necessities with lowest expenditure elasticities of 0.74 and 0.99 respectively. On the other hand, fresh tomato and pepper are luxury items with expenditure elasticities greater than 1 at 1.04 and 1.15 respectively. Further, fruit has the highest expenditure elasticity of 2.23 indicating that despite the rapid expansion of fruit consumption that has taken place, as incomes increase, a more than proportionate share of that additional income is going to fruit consumption.

Second, in the South, low expenditure elasticities are observed for onions (0.65), pepper (0.83), okra (0.84), and fresh tomato (0.87). Our results indicate that these vegetables are necessities in both urban and rural South. However, tomato paste is still a luxury in both areas of the South. Fruit exhibits the highest expenditure elasticity (1.28) again depicting that the demand for fruit will continue to increase with incomes.

Third, we note some interesting differences in urban and rural areas of the North. While fresh tomato and pepper are luxury items in the North overall, disaggregation across urban and rural areas suggests that these results are driven by high expenditure elasticities for these items in rural areas (1.04 for tomato and 1.15 for pepper). In the urban North, the elasticities although high are still less than 1 (0.94 for both pepper and fresh tomato).

Table 1.10 describes expenditure elasticities across income groups and over regions. We note some interesting similarities and differences across income groups within a region as well as across income groups in different regions.

First, in the North, onion is a staple vegetable and a necessity having low expenditure elasticities. Interestingly, despite being a staple, expenditure elasticity for onion is the highest among the richest group (0.83) and the lowest among the poorest group (0.75). This may be because of the consumption of higher quality onions among the rich, increasing their expenditure on onions. While pepper, tomato, and okra exhibit high elasticities above 0.95 across all income groups, these items are a luxury among the poorest tercile with expenditure elasticities of 1.28, 1.08, and 1.02 respectively. Fruit, however, exhibit very highest expenditure elasticities across all income groups and as expected decline with income (2.45 for the poorest and 1.88 for the richest).

Second, in the South, expenditure elasticities for important vegetables namely onion, fresh tomato, okra, and pepper are low and lower than the North across all income groups. Similar to the North, expenditure elasticities for fruit are the highest among all FV items at 1.28 for the poorest and 1.14 for the richest.

Third, as expected, the poorest in the North have high expenditure elasticities for all FV items than those in the same income group in the South.

Table 1.11 describes price elasticities across for different food groups and FV items across regions. As expected and consistent with the demand theory, own-price elasticities are negative for all food groups and different sources of animal proteins. In the North, all FV items have own-price elasticity of absolute value less than 1 except for fruits. This indicates that a 1% increase in prices reduces the quantity demanded by less than 1% for all items except for fruits. This suggests that despite the rapid expansion of fruit, North Nigerians are sensitive to price changes.

In the South, however, absolute values of price elasticities are less than 1 for all items including fruit. In fact price elasticity of fruit is only -0.79 exhibiting that fruits are an established component of diets in Southern Nigeria and its demand is not very sensitive to price changes.

Further, cross-price elasticities display some interesting results. First, in the South, our descriptive analysis suggested that tomato paste is an important product. Positive but very low absolute cross-price elasticities between fresh tomato and tomato paste suggest that these items are not really substitutes for each other.

Second, among the important vegetables, we note positive cross-price elasticities for some items. For example, increase in the price of onion increases fresh tomato and tomato paste consumption as evidenced by positive cross-price elasticity of 0.10 and 0.07 respectively. Further, increase in the price of pepper increases fresh tomato consumption (0.15). Although low these positive cross-price elasticities are evidence of versatility of tomato and its ability to easily replace other vegetables. Increase in the price of fresh tomato, however, decreases onion consumption as indicated by cross price elasticity of -0.23 but increases okra consumption (cross price elasticity 0.10). This further suggests that South Nigerians reduce onion consumption (which they consume in high quantities) when tomato prices increase, possibly to buy more of fresh tomato. Overall, such low cross-price elasticities are explained by low own-price elasticities, meaning South Nigerians are not so sensitive to prices and hence do not need to replace items in the light of increased prices.

Third, in the North, fruit displays the highest own-price elasticity and surprisingly displays negative and large cross-price elasticity with animal proteins (-0.88) and other veg (-0.14) but positive cross price elasticities with cereals and pulses (0.23 and 0.26 respectively).

1.6. Discussion

Our regression results together with descriptive statistics bring out important insights about FV consumption in Nigeria for different items. We discuss key points for each FV item below.

1.6.1. Onions

Onions are the most popular FV item consumed all over Nigeria with almost all households across regions and income groups consuming them in a typical week. The ubiquity of onion consumption is explained by onions being a versatile and basic ingredient in most sauces that accompany basic grain and roots and tuber staple dishes in the country; the onion flavor bolsters and easily combines with many other ingredients, from traditional leaf and okra-based sauces to more non-traditional tomato-based sauces. Onions are also used for frying eggs and in dishes that mix rice or other starchy staples such as fried or jollof rice. Our low expenditure elasticities for onions confirm that this is indeed a necessity among all income groups in urban as well as rural areas of both North and South.

1.6.2. Peppers

Peppers are another widely consumed FV item in both North and South with high share of consumers. As with onions, peppers are versatile and spice up a wide range of dishes. Though believed to be recent, this confirms that hot peppers are ingrained in the Nigerian diet and higher and constant consumption of hot peppers in the South resonates with anecdotal evidence that consumption is particularly high in Southern Nigeria.

1.6.3. Tomatoes

Fresh tomatoes are another important item with consumer share of about 80% in both regions. This similarity is surprising as tomato production predominantly takes place in the North; thus reflecting the importance of long supply chains moving perishable commodities all over the country. Tomato paste (mostly imported) is also an important product particularly in the South. Surprisingly, tomato paste consumption has also penetrated Southern rural areas possibly due to its reliance on the North for supply of fresh tomatoes and longer shelf-life.

While these levels and the above evidence of widespread consumption of tomatoes may not strike an urban Nigerian reader as surprising as "jollof rice" (rice with tomato and onion sauce) is nowadays very popular in cities, the finding is surprising from two perspectives.

On the one hand, the ubiquity of tomato consumption is surprising from the perspective of recent history, over the past 50 years. Tomatoes originated in Mexico and came to Nigeria as a non-traditional food. FAOSTAT shows tomatoes and tomato products at 325k tons in 1980, 375k tons in 1990, 1261k tons in 2000, 1800k tons in 2010, and 3816k tons in 2019! Tomato output grew 12-fold in 40 years, while national population only grew 2.7-fold! This can be compared with onion output (and consumption as it is not imported) growing 3-fold in the same period. That is, the spread of tomato-based or tomato-enhanced sauces spread 5 times faster than population growth, a revolution in basic food habits. We emphasize sauces because casual observation points to a general dearth so far of "tomato salad" or "lettuce and tomato salad" phenomena.

On the other hand, it is surprising from a "food culture" perspective that even rural areas, conventionally seen as bastions of food traditions, are adopting tomato consumption, linked to rising rice consumption. The rural traditional diet features a staple base of yams in the South (as one sees in the book The Arrow of God by Chinua Achebe published in 1964). By today, one sees tomato-based dishes in the same areas where yam reigned; and apparently because of supply constraints nationally but especially in rural areas, many rural Nigerian households especially (and urban also) are consumed tomato paste (from tomatoes produced mainly in China as noted in the introduction here).

The adoption of non-traditional rice-based dishes is in general linked to the rise of demand for convenience staples and has been going on for decades (Kennedy and Reardon, 1994). The demand for convenience is often only associated with urban areas but in rural areas in Nigeria, rural nonfarm employment is ubiquitous and creates opportunity costs of time for home preparation. This makes rice attractive as it is easy in preparation. Non-traditional and spicy (and considered delicious) tomato, onion, and pepper sauce in jollof rice is then the complement to rice and they rise together. The surprise is how it is penetrating rural areas, but it is less surprising that this is happening in the more developed South rural areas than in the North rural areas.

1.6.4. Okra

Okra (a traditional African vegetable) is important but more popular in the poorer North than the affluent South. Despite the widespread adoption of non-traditional dishes as regular food (e.g., tomato-based sauce of jollof rice), traditional sauces using okra are still consumed in both the poorer North and the more prosperous South. What is surprising, however, is the lack of a sharp negative correlation with income at least in share of households per tercile; one might have expected richer households to have "westernized" away from traditional vegetables, but one sees that that has not happened. This may be because certain popular soups, like okra soup, differs between poor and rich not by the okra taste but by the amount and quality of the animal protein in it. In that sense the Nigerians keep to a traditional pattern of a common "gluey vegetable" base but add what used to be luxury sources of meat and fish among the richer households. Yet, we noted a sharp decline in the per capita okra consumption in the North (similar to peppers and tomatoes). Such a decline even in the traditional vegetable along with other "westernized" vegetables is worrisome because real mean prices (as seen in Table 1.1) did not increase over time.

1.6.5. Green Leafy Vegetables

Anecdotally, GLVs were traditionally an important FV item in Nigerian diets. Keep in mind that these are nearly always cooked into sauces and typically not consumed raw in salads. These are also a mix of traditional gathered leaves (such as of baobab trees in the North *(kuka)* and *efo yanrin* (wild lettuce, in the aster family) in the South), farmed traditional leaves (such as *efo ewuro* (bitter leaf, in the aster family), gbure (waterleaf, in the purslane family), efo tete (African spinach, in the amaranth family); and non-traditional leaves such as spinach (of Asian origin introduced to Nigeria over the past century). Our data do not allow disaggregation. It appears that the traditional leaves were all gathered only centuries ago and now mainly marketed.

Our results for GLVs are very surprising. Our data shows a very low consumption share until 2015/16 and then a sharp jump between 2018/19. We do not know if this is a jump in traditional or non-traditional GLVs. Moreover, surprising is that the share of households in urban areas is about 1.5 times that in rural areas in every year of the series. It may be that there is some common set of traditional GLVs consumed by each area, and more of the luxury non-traditional leaves consumed in cities. This cannot be tested with our aggregated data. Also, the average share of households consuming GLVs was twice as high in the South compared to the North, and shares in urban areas were a little below those in rural areas. It is hard to interpret these results without having the GLVs disaggregated into traditional and non-traditional, into gathered and regular and luxury items, but the overall picture is the South seeking GLVs more than the North perhaps for taste reasons, and for supply reasons. GLVs are typically not long-distance traded, so local production counts a lot. The South has much wetter conditions year-round that would favor leafy greens production.

Other vegetables such as African eggplant and Irish potatoes are consumed in the home by fewer Nigerian households than the above mainly non-traditional vegetables. Within this general point there are two items that tell an important story of transformation.

1.6.6. African Eggplant

African eggplant, the only (genetically) indigenous vegetable was traditionally one of the important vegetables consumed apart from okra and a subset of green leafy vegetables. It is striking that what was once an extremely common traditional vegetable in Nigerian cuisine has dropped to a limited share of households consuming it now. Anecdotal evidence indicates that the consumption of the garden egg fruit (sometimes with peanut paste) remains a well-known snack. However, we do not see any evidence of the dominance of this traditional vegetable in Nigerian diets today. This may be because of supply constraints, but also may be because of the stiff competition with so many non-traditional vegetables. We also note that the share per tercile of African eggplant jumps sharply with income in both North and South. This shows, as with okra, that the traditional vegetables that have withstood over time the avalanche of foreign vegetables planted on Nigeria soil, are still highly appreciated and even treated as a somewhat luxury food, even though the shares of households eating them are now limited. The dominance of eggplant consumption in both regions among urban consumers is consistent with the observed niche role of egg-plant consumption as a ready to eat snack either by itself or with peanuts or peanut paste.

1.6.7. Potato

Irish potato, a non-traditional vegetable, introduced to Nigeria by Europeans but originating genetically in South America, has attained a foothold but is still limited in consumption. This is possible because it does not "integrate" as easily into traditional sauces (where chunky ingredients are less welcomed as the sauce is used to accompany the eating of a ball of staple grains or roots/tubers mash), and because stand-alone potato consumption such as in French fries is not yet a common home-prepared staple among a wide range of Nigerians. Irish potatoes are more commonly consumed in the North compared to the South. Irish potato in the North is more commonly consumed in urban areas than rural areas, indicating a hypothesis of Irish potatoes being more of a luxury. However, in the South the low share of consuming households is similar between rural and urban households. While the consumption of Irish potatoes as fries is likely captured in the rapid expansion of food away from home consumption, we do not find evidence of its expansion in home prepared meals in Nigeria.

1.6.8. Fruits

These are striking findings again from historical and comparative perspectives. The surge in fruit consumption and its share in FV stands in contrast to "conventional wisdom" which has fruits not being widely consumed in lower income countries. Moreover, the image of fruits ascendance clashes with the traditional view of fruit in Nigerian foodways. In the past, indigenous fruit (rare in diets nowadays) was usually just gathered from forest and bush areas and was an occasional 'treat' especially for children, and very seasonal. Non-traditional fruit oranges have grown to predominate. But fruit was a luxury and a minor part of the diet. To witness in the data the ubiquity of consumption now, and grown over such a short period as a decade, is striking. Such expansion in fruit consumption is primarily due to increase in the consumption of particularly bananas and oranges.

To summarize, in the North, the "big four vegetables" (fresh tomatoes, onions, peppers, and okra) dominate the FV budget in both rural and urban areas. Yet we see that their share fell over the period, largely ceding to the rise of fruit. In contrast the share of relatively cheaper GLVs in the north has increased significantly. In the South, the same "big four" dominate, but are joined by tomato paste as the main "package." Again, their share together in FV fell over the period with the rise of the share of fruit.

1.7. Conclusion

Our nationally representative demand analysis of FV reiterates that consumption of FV is increasing with increasing incomes but is still much lower than the nutritionally recommended amounts in all regions and across income groups. We conducted disaggregated analysis of FV food group to assess demand for different types of vegetables and fruits. Several interesting points stood out. We found that diets have "westernized" with onions, tomato, peppers being the most popular forms of FV in both North and South of Nigeria. Moreover, fruit consumption has seen a rapid expansion over the last decade. Among traditional vegetables, while okra is still an important FV item, eggplant is more of a luxury product. Additionally, non-traditional potato has limited popularity and consumption in Nigeria unlike other countries like India and China where it has become very popular in a short time.

Our findings have important policy implications for further development of FV production and supply chains. In contrast to the decline in per capita consumption of most vegetables in the North, there has been a significant increase in the consumption of relatively cheaper GLVs. This is important for the debate to promote increased consumption of FV in the poorer North where food insecurity and malnutrition are highest.

Further, although vegetable consumption in the South has increased and is higher than the poorer North, per capita quantities are way below the recommended levels. Our findings suggest that there is reliance on convenient-to-use items in the South. Thus producing and promoting such products may help increase FV consumption in the South.

Additionally, the ubiquitous expansion of fruit consumption in Nigeria is worthy of note. This is also an opportunity for the Nigerian government and donors to explore and support the domestic supply chains that produce and distribute fruits in the country.

Finally, the rapid rise and role especially in the South of tomato paste, imported mainly from China, indicates excess demand for tomatoes and constraints to production and/or supply chains of fresh tomatoes. It is also an opportunity for Nigerian entrepreneurs to produce tomato paste, and policies and infrastructure to make that processing foray feasible are called for.

Apart from malnutrition, developing countries also face a challenge of ramping up food production in an environmentally sustainable manner as demand for nutrient-dense foods increases with rising incomes. Demand for animal proteins is expected to increase considerably over the next few decades and is very likely to pose a threat to environmental sustainability. A shift away from animal proteins to FV could reduce increasing greenhouse gas emissions and help control excessive use of land and water while providing sufficient micronutrients to fight malnutrition.

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APPENDIX

Tables

Table 1.1: Mean real prices (in Naira)

	2010-2011			2012-2013			2015-2016			2018-2019		
Food groups	North	South	All	North	South	All	North	South	All	North	South	All
Cereals	122	180	153	117	221	174	123	196	164	97	169	133
Tubers	94	114	107	81	117	105	64	100	88	60	74	68
Pulses	155	143	148	165	262	221	139	170	157	220	347	286
Oils	288	302	296	249	262	256	240	322	287	256	416	338
Animal proteins	586	646	622	636	539	578	525	510	516	411	456	437
Dairy	524	952	809	358	950	760	324	740	569	638	985	858
Fruit	141	137	138	132	197	182	111	194	171	43	59	53
Okra	219	240	228	199	170	185	195	198	196	356	147	259
Onion	167	259	217	99	126	115	95	93	94	85	99	93
Pepper	397	524	472	152	197	180	223	152	179	119	104	110
Tomato (Fresh)	135	158	147	78	116	99	147	158	153	104	116	110
Tomato paste	271	293	291	109	198	191	394	424	420	332	333	333
Potato	114	108	114	89	113	95	126	118	124	75	67	73
Eggplant	143	173	162	78	101	93	58	77	72	64	59	61
GLV	220	260	238	58	81	70	169	201	175	172	232	212
Other veg	204	245	234	130	133	132	466	569	524	246	268	257
Other foods	260	299	279	146	146	146	200	223	213	159	156	157
Number of households	2494	2493	4987	2400	2310	4710	2312	2268	4580	2510	2465	4975

Table 1.2: Consumption of fruit and vegetable (FV) as a food group by region over time

	North				South			
	2010-11	2012-13	2015-16	2018-19	2010-11	2012-13	2015-16	2018-19
				Share of households (%)				
FV combined	98	99	99	100	99	99	100	99
Fruit	32	34	50	63	58	77	89	83
Vegetable	98	99	99	100	99	99	100	99
				Share of food budgets (%)				
FV combined	12	9	10	13	13	11	14	16
Fruit	1	1	2	2	2	3	5	4
Vegetable	11	8	8	11	11	8	9	12
				Daily per capita consumption (grams)				
FV combined	148	142	102	148	127	133	154	225
Fruit	19	14	38	71	38	46	85	110
Vegetable	129	128	64	77	89	87	68	114
Number of households (N)	2494	2400	2312	2510	2493	2310	2268	2465

Table 1.3: Share of consumers by areas (urban vs rural) and over time in North and South

	2010-2011			2012-2013			2015-2016			2018-2019		
NORTH												
Food groups	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All
Fruit and vegetables	98	98	98	99	98	99	99	99	99	100	100	100
Fruit	50	27	32	48	30	34	59	48	50	78	59	63
Other veg	26	13	16	37	42	41	24	33	31	33	30	30
Okra	75	77	76	77	77	77	72	76	75	75	74	74
Onion	94	90	91	94	92	92	97	95	96	99	97	98
Pepper	86	81	82	87	77	79	85	77	79	85	66	70
Tomato (Fresh)	92	80	83	92	81	83	96	86	89	93	77	80
Tomato paste	14	8	9	13	7	9	15	8	10	12	7	8
Potato	17	5	8	16	8	10	16	7	9	8	4	5
Eggplant	18	15	16	18	13	14	13	11	12	9	10	10
GLV	21	12	14	17	10	12	3	7	6	38	29	31
Cereals	99	99	99	100	100	100	99	100	100	99	100	100
Tubers	78	65	68	85	77	79	83	75	77	87	81	82
Pulses	90	83	85	93	86	87	95	93	94	98	96	96
Oils	97	97	97	99	99	99	91	98	96	100	99	99
Animal proteins	95	87	89	99	90	92	98	89	91	94	87	89
Dairy	59	39	44	58	42	46	52	40	43	68	46	51
Other foods	96	92	93	99	98	98	100	98	99	100	100	100
Number of households	528	1966	2494	486	1914	2400	486	1826	2312	532	1978	2510
SOUTH												
Food groups	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All
Fruit and vegetables	98	99	99	99	100	99	99	100	100	98	99	99
Fruit	61	55	58	74	80	77	88	91	89	86	80	83
Other veg	36	29	33	55	70	62	25	38	31	19	36	29
Okra	45	51	48	49	73	60	56	71	63	61	69	66
Onion	89	89	89	94	96	95	98	99	99	98	99	99
Pepper	92	88	90	91	92	92	95	91	94	91	92	92
Tomato (Fresh)	85	68	77	88	69	79	95	86	91	92	75	82

Table 1.3 (cont'd)

Tomato paste	48	57	52	53	64	58	38	60	48	54	61	58
Potato	1	1	1	3	3	3	3	4	4	1	3	2
Eggplant	19	22	20	17	22	19	18	31	24	19	20	19
GLV	11	9	10	10	13	11	1	1	1	44	57	52
Cereals	98	96	97	99	99	99	100	100	100	99	99	99
Tubers	95	88	92	99	100	100	99	100	99	99	100	99
Pulses	90	92	91	90	88	89	94	96	95	96	98	97
Oils	94	92	93	99	100	99	99	100	99	99	99	99
Animal proteins	99	99	99	99	100	99	99	100	100	99	99	99
Dairy	70	52	62	76	59	68	54	44	50	81	75	77
Other foods	85	76	81	96	98	97	92	97	94	100	100	100
Number of households (N)	1085	1408	2493	984	1326	2310	980	1288	2268	1056	1409	2465

For descriptive statistics, we included all households who consumed a particular item in the week prior to the survey in either of and both post planting and post-harvest. This increases the consumption values for different food items significantly compared to just using the share who consumed in either period separately. This might be because of seasonal accessibility and affordability constraints of a household. Thus, measuring yearly consumption allows us to get a better sense of desirability of products.

Table 1.4: Share of consumers by per capita income (proxied by expenditure)**

	2010-2011			2012-2013			2015-2016			2018-2019		
NORTH												
	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
Fruit and vegetables	97	99	98	98	99	99	99	100	98	99	100	98
Fruit	14	34	52	21	33	57	41	67	80	54	73	85
Other veg	9	17	24	43	39	45	32	30	24	32	30	20
Okra	74	78	76	72	79	80	74	79	70	73	78	71
Onion	84	93	95	87	95	95	95	96	98	97	99	97
Pepper	77	84	85	69	82	90	76	85	79	61	79	91
Tomato (Fresh)	74	85	88	77	85	89	87	92	93	73	89	89
Tomato paste	6	9	16	4	8	17	7	17	17	5	10	17
Potato	5	7	14	7	10	13	7	11	22	2	5	21
Eggplant	12	17	19	10	15	17	11	12	9	7	13	18
GLV	9	16	17	8	12	16	6	6	5	26	35	44
Cereals	99	100	99	100	100	100	100	100	100	100	100	98
Tubers	57	70	78	70	80	89	72	85	94	76	90	89
Pulses	74	89	89	81	89	93	93	95	95	96	98	95
Oils	94	99	96	98	99	99	96	96	91	99	100	99
Animal proteins	75	94	97	83	95	99	88	98	99	84	94	96
Dairy	26	43	65	38	44	65	38	51	58	36	66	81
Other foods	88	94	96	96	99	100	98	100	100	100	100	100
Number of households (N)	724	1151	619	725	1189	486	1550	642	120	1425	836	249
SOUTH												
	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
Fruit and veg	98	99	99	99	100	99	100	100	99	100	99	98
Fruit	33	51	72	65	78	79	83	92	96	72	81	89
Other veg	19	29	40	62	67	58	32	29	33	43	29	23
Okra	43	47	50	66	64	55	61	64	64	75	66	61
Onion	81	89	92	92	96	95	98	100	98	99	99	98
Pepper	83	92	91	91	92	92	91	96	93	84	94	91
Tomato(Fresh)	60	76	83	58	74	87	88	92	92	69	83	87
Tomato paste	41	47	59	50	58	60	39	49	61	55	57	61
Potato	0	1	1	1	2	3	1	4	6	1	2	3
Eggplant	13	18	24	14	19	20	17	24	33	12	18	24

Table 1.4 (cont'd)

GLV	9	11	10	16	12	10	1	1	2	54	52	51
Cereals	91	97	99	96	99	100	100	100	99	100	99	99
Tubers	76	93	96	98	100	99	99	100	99	100	100	99
Pulses	81	92	93	72	89	93	94	95	95	98	97	96
Oils	85	92	96	98	100	99	100	100	98	100	99	98
Animal proteins	97	99	100	99	100	99	100	100	99	99	99	98
Dairy	25	55	80	33	62	80	33	53	72	50	77	89
Other foods	57	79	91	93	98	98	94	94	96	100	100	100
Number of households (N)	484	980	1029	348	911	1051	885	956	427	412	1232	821

**Terciles are created based on average per capita daily total expenditure of a household in both seasons (pre-harvest and post harvest : Tercile 1: less than or equal to $1.9, Tercile 2: between $1.9 and $4, Tercile 3: greater than $4.

Table 1.5: Annual per capita consumption over time and regions (kg)

	2010-2011			2012-2013			2015-2016			2018-2019		
	NORTH											
Food groups	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All
Fruit and vegetables	66.1	50.3	54.1	69.2	47.2	52.0	53.6	32.2	37.2	73.4	48.8	53.9
Fruit	11.8	5.6	7.1	8.5	4.4	5.3	22.9	11.2	13.9	38.5	22.5	25.8
Okra	7.2	8.2	8.0	3.4	4.8	4.5	2.6	2.4	2.5	2.5	2.6	2.6
Onion	10.8	9.8	10.1	9.8	7.2	7.8	8.0	7.1	7.3	9.7	8.1	8.5
Pepper	6.9	5.8	6.1	5.1	4.2	4.4	3.9	2.4	2.7	5.1	3.2	3.6
Tomato (Fresh)	19.8	15.0	16.2	32.8	21.1	23.7	11.3	6.5	7.6	11.0	6.8	7.7
Tomato paste	1.5	0.7	0.9	0.6	0.5	0.5	0.3	0.1	0.2	0.2	0.1	0.1
*Tomato paste (FE)**	*8.4*	*4.0*	*5.1*	*3.2*	*2.9*	*2.9*	*1.7*	*0.8*	*1.0*	*0.9*	*0.7*	*0.7*
Potato	4.6	2.3	2.8	6.4	2.9	3.7	3.5	1.3	1.8	1.4	1.3	1.3
Eggplant	1.0	1.2	1.2	0.7	0.7	0.7	0.6	0.6	0.6	0.5	0.6	0.6
GLV	1.2	0.9	1.0	1.1	0.5	0.6	0.1	0.2	0.2	3.8	3.2	3.3
Other veg	1.3	0.7	0.8	1.0	0.8	0.9	0.3	0.3	0.3	0.6	0.3	0.3
Cereals	184.6	229.9	219.1	159.0	188.2	181.8	138.6	165.9	159.5	118.2	146.7	140.8
Tubers	79.3	78.1	78.4	80.2	73.5	75.0	100.1	103.7	102.9	64.8	76.8	74.3
Pulses	31.3	30.0	30.3	31.3	40.7	38.6	17.4	19.8	19.3	15.5	16.9	16.6
Oils	24.1	19.2	20.4	18.2	15.7	16.3	13.7	12.2	12.6	12.5	11.1	11.4
Animal proteins	29.6	20.0	22.3	35.4	14.5	19.1	18.4	11.7	13.3	18.5	12.5	13.8
Dairy	7.8	5.9	6.4	4.5	5.3	5.1	4.5	4.3	4.3	3.0	3.5	3.4
Other foods	52.8	24.4	31.2	48.4	20.5	26.6	37.9	13.8	19.4	129.2	32.8	52.6
Number of households (N)	528	1966	2494	486	1914	2400	486	1826	2312	532	1978	2510
	SOUTH											
	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All
Fruit and veg	49.0	43.5	46.5	49.0	47.9	48.5	58.8	52.9	56.1	85.0	79.9	82.0
Fruit	14.6	13.0	13.8	16.8	16.5	16.7	32.0	30.1	31.1	42.5	38.7	40.3
Okra	1.8	3.2	2.4	1.6	2.6	2.1	1.7	2.3	2.0	2.8	3.7	3.3
Onion	5.1	4.8	4.9	4.7	4.4	4.5	7.0	6.6	6.8	10.0	10.0	10.0
Pepper	6.9	5.1	6.1	5.3	4.0	4.7	5.9	3.7	4.9	8.4	6.8	7.4
Tomato (Fresh)	13.0	8.9	11.1	13.6	10.0	11.9	9.8	6.4	8.2	12.9	9.1	10.7
Tomato paste	3.5	4.8	4.1	2.4	4.3	3.3	0.7	1.0	0.8	1.3	1.6	1.5

Table 1.5 (cont'd)

*Tomato paste (FE)**	*19.5*	*27.1*	*23.0*	*13.6*	*23.8*	*18.4*	*3.7*	*5.9*	*4.7*	*7.5*	*8.7*	*8.2*
Potato	0.4	0.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.1	0.3	0.2
Eggplant	1.1	1.1	1.1	1.0	1.2	1.1	1.2	2.1	1.6	1.7	1.7	1.7
GLV	0.6	0.8	0.7	0.5	0.7	0.6	0.0	0.0	0.0	4.9	7.6	6.5
Other veg	2.0	1.8	1.9	2.8	3.8	3.3	0.3	0.3	0.3	0.1	0.3	0.2
Cereals	72.2	61.0	67.1	45.5	37.1	41.6	47.5	41.2	44.7	49.7	50.6	50.2
Tubers	113.2	106.8	110.2	106.4	139.1	121.7	112.0	175.1	140.7	120.0	204.8	169.3
Pulses	30.4	32.2	31.2	14.7	13.7	14.2	16.2	12.2	14.4	16.5	18.7	17.8
Oils	26.5	25.2	25.9	12.2	11.2	11.7	11.8	11.3	11.6	12.1	12.0	12.1
Animal proteins	35.1	35.2	35.1	26.1	23.4	24.9	28.0	24.2	26.3	31.3	32.9	32.2
Dairy	5.0	14.0	9.2	2.8	2.6	2.7	2.3	1.8	2.0	3.0	2.1	2.5
Other foods	87.8	25.1	58.9	90.2	24.4	59.5	27.5	18.3	23.3	140.8	76.0	103.1
Number of households (N)	1085	1408	2493	984	1326	2310	980	1288	2268	1056	1409	2465

* *FE* denotes fresh equivalent. 1kg of tomato paste = 5.6 kg of fresh tomato

Table 1.6: Annual per capita consumption of FV over income terciles (proxied by expenditure) (kg)

	2010-2011			2012-2013			2015-2016			2018-2019		
NORTH												
Food groups	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
Fruit and vegetables	32.8	52.3	82.9	29.9	52.1	87.2	24.8	52.5	110.2	33.1	67.4	129.2
Fruit	1.2	5.8	16.4	1.7	3.8	15.0	6.8	22.0	58.5	14.4	32.5	69.5
Okra	6.8	8.0	9.3	3.1	4.2	7.3	2.1	3.1	3.8	2.0	3.1	4.1
Onion	7.0	9.8	14.2	5.9	7.5	11.4	6.0	9.1	13.5	6.5	10.5	13.3
Pepper	4.9	5.9	7.9	2.5	4.6	6.7	2.0	3.8	6.1	2.3	4.7	7.6
Tomato (Fresh)	10.4	16.2	23.0	14.2	24.8	35.9	5.7	10.6	15.8	4.9	9.9	16.7
Tomato paste	0.2	0.8	1.8	0.2	0.4	1.3	0.1	0.3	0.6	0.0	0.1	0.6
*Tomato paste (FE)**	*1.4*	*4.7*	*10.1*	*0.9*	*2.5*	*7.4*	*0.4*	*1.7*	*3.4*	*0.3*	*0.8*	*3.2*
Potato	0.8	2.6	5.7	1.1	4.5	5.7	1.1	1.9	10.1	0.4	1.1	7.6
Eggplant	0.6	1.3	1.6	0.3	0.8	1.2	0.5	0.9	0.9	0.3	0.7	2.1
GLV	0.4	1.0	1.6	0.3	0.7	1.1	0.2	0.3	0.4	2.0	4.4	7.3
Other veg	0.4	0.8	1.5	0.6	0.8	1.6	0.3	0.3	0.5	0.3	0.5	0.4
Cereals	168.4	230.2	259.6	157.5	190.3	198.5	149.6	183.8	152.7	129.5	157.5	147.2
Tubers	36.9	73.6	137.2	31.0	79.3	134.1	72.4	149.2	233.0	52.0	99.0	118.0
Pulses	17.0	32.2	42.8	26.0	41.0	52.5	17.0	22.7	28.6	13.4	20.2	22.3
Oils	12.6	20.4	29.9	9.5	14.8	31.0	10.7	15.3	21.1	8.4	14.3	19.0
Animal proteins	9.5	20.5	41.0	6.7	15.8	47.9	8.0	20.0	42.7	6.8	18.9	37.2
Dairy	4.0	5.6	10.6	4.3	5.2	6.0	3.7	5.2	7.4	2.7	4.2	4.7
Other foods	11.5	21.7	72.4	8.5	21.0	70.4	9.4	29.4	91.5	19.6	64.0	210.7
Number of households	724	1151	619	725	1189	486	1550	642	120	1425	836	249
SOUTH												
Food groups	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
Fruit and vegetables	21.4	38.1	61.9	24.2	37.0	62.3	31.3	58.4	94.6	37.2	69.1	117.8
Fruit	3.6	9.8	20.7	7.5	10.8	23.0	14.4	31.4	59.7	15.7	30.5	63.8
Okra	1.5	2.1	3.0	1.7	2.0	2.2	1.4	2.0	2.9	2.8	3.1	3.9
Onion	3.2	4.1	6.2	2.6	3.9	5.5	4.8	7.3	9.2	5.5	9.4	12.7
Pepper	3.1	5.7	7.4	2.9	3.7	5.9	3.5	5.3	6.3	3.2	7.2	9.4
Tomato (Fresh)	5.4	9.8	14.2	4.7	8.4	16.1	5.6	9.1	11.1	4.5	9.8	14.5
Tomato paste	2.4	3.2	5.4	1.4	3.4	3.6	0.4	0.8	1.6	0.7	1.3	2.0

Table 1.6 (cont'd)

*Tomato paste (FE)**	*13.6*	*18.2*	*30.2*	*8.1*	*19.2*	*20.0*	*2.4*	*4.7*	*8.7*	*3.9*	*7.1*	*11.5*
Potato	0.0	0.2	0.4	0.1	0.2	0.4	0.1	0.4	0.4	0.1	0.2	0.4
Eggplant	0.5	0.9	1.4	0.5	0.7	1.5	0.7	1.7	2.9	0.7	1.4	2.6
GLV	0.6	0.8	0.7	0.7	0.6	0.7	0.0	0.0	0.1	3.7	6.0	8.3
Other veg	1.0	1.5	2.6	2.0	3.4	3.5	0.2	0.3	0.4	0.4	0.2	0.2
Cereals	41.0	53.4	87.2	19.5	34.0	52.0	31.6	47.7	61.0	28.8	46.5	63.9
Tubers	43.0	101.8	139.8	87.6	116.7	132.8	113.3	152.8	163.0	131.0	170.9	182.2
Pulses	19.7	28.1	37.7	5.4	12.1	17.6	10.2	14.9	20.6	10.8	16.4	22.5
Oils	11.5	21.1	34.8	6.6	9.7	14.4	8.1	12.1	16.4	6.7	11.1	15.6
Animal proteins	14.4	26.5	49.3	9.2	17.4	33.8	15.0	27.1	44.2	11.3	26.6	48.4
Dairy	5.2	6.0	13.1	0.6	1.7	3.8	0.7	1.8	4.9	1.0	1.8	4.0
Other foods	6.3	36.1	95.7	5.9	25.7	95.9	6.9	22.8	53.3	24.7	58.9	196.3
Number of households	484	980	1029	348	911	1051	885	956	427	412	1232	821

**Terciles are created based on average per capita daily total expenditure of a household in both seasons (pre-harvest and post harvest : Tercile 1: less than or equal to \$1.9, Tercile 2: between \$1.9 and \$4, Tercile 3: greater than \$4.

* *FE* denotes fresh equivalent. 1kg of tomato paste = 5.6 kg of fresh tomato

Table 1.7: Annual per capita consumption over time and regions (kg)

	2010-2011			2012-2013			2015-2016			2018-2019		
						NORTH						
Food groups	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All
Fruit	12.4	5.8	7.4	11.1	7.4	8.3	17.6	12.0	13.3	21.2	15.2	16.4
Okra	12.6	18.5	17.0	13.9	19.6	18.3	9.3	13.4	12.4	11.1	18.3	16.8
Onion	19.6	23.1	22.2	18.8	21.2	20.7	18.5	24.5	23.1	21.0	29.0	27.3
Pepper	17.6	20.5	19.8	14.7	15.0	15.0	14.7	13.9	14.1	12.8	9.7	10.4
Tomato (Fresh)	26.6	24.2	24.8	29.9	27.2	27.8	30.2	25.9	26.9	23.2	18.2	19.2
Tomato paste	2.0	1.6	1.7	2.0	0.7	1.0	2.6	1.4	1.7	1.2	0.8	0.8
Potato	3.7	1.3	1.9	4.4	2.1	2.6	3.5	1.6	2.1	1.1	0.9	1.0
Eggplant	1.3	1.8	1.7	1.0	1.4	1.3	0.8	1.1	1.0	0.5	0.7	0.7
GLV	1.6	1.6	1.6	1.1	0.9	0.9	0.3	0.9	0.7	6.5	5.3	5.5
Other veg	2.7	1.7	1.9	3.0	4.4	4.1	2.5	5.3	4.6	1.4	2.0	1.9
Number of households	528	1966	2494	486	1914	2400	486	1826	2312	532	1978	2510
						SOUTH						
Food groups	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All
Fruit	16.4	14.8	15.7	20.1	26.5	23.1	31.1	34.9	32.8	24.5	22.1	23.1
Okra	4.8	7.3	5.9	5.7	9.9	7.6	5.7	8.4	6.9	6.5	8.7	7.8
Onion	16.3	17.8	17.0	13.1	12.3	12.7	13.4	13.6	13.5	17.2	17.4	17.3
Pepper	22.2	22.7	22.5	20.9	13.6	17.5	17.2	11.6	14.6	13.7	10.8	12.0
Tomato (Fresh)	24.5	17.5	21.3	26.9	16.4	22.0	25.1	18.2	21.9	21.4	14.8	17.6
Tomato paste	7.9	11.9	9.7	4.2	8.8	6.3	4.1	7.3	5.6	6.9	7.8	7.4
Potato	0.2	0.1	0.2	0.4	0.4	0.4	0.3	0.3	0.3	0.1	0.3	0.2
Eggplant	1.9	2.5	2.2	1.4	2.1	1.7	1.1	2.2	1.6	1.3	1.3	1.3
GLV	1.7	1.2	1.5	0.8	1.2	1.0	0.1	0.0	0.1	7.9	15.3	12.2
Other veg	4.1	4.2	4.2	6.5	8.9	7.6	2.0	3.4	2.6	0.7	1.5	1.1
Number of households	1085	1408	2493	984	1326	2310	980	1288	2268	1056	1409	2465

Table 1.8: Annual per capita consumption over income terciles (proxied by expenditure) (kg)

	2010-2011			2012-2013			2015-2016			2018-2019		
						NORTH						
Food groups	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
Fruit	3.0	6.7	13.5	5.0	7.6	15.0	9.3	19.4	29.5	13.4	18.4	26.9
Okra	20.9	16.9	12.8	20.9	18.2	14.8	13.8	10.2	8.1	19.1	14.9	9.8
Onion	23.0	22.4	21.2	23.0	20.3	18.3	25.3	19.5	15.6	30.1	25.6	17.3
Pepper	22.3	19.9	16.7	14.3	15.7	14.3	14.4	13.9	11.8	9.8	10.9	11.5
Tomato (Fresh)	23.8	25.2	24.9	26.8	29.0	26.5	27.3	26.5	24.3	18.5	20.3	19.4
Tomato paste	1.2	1.6	2.4	0.6	1.0	1.6	1.1	2.8	2.9	0.7	0.9	1.8
Potato	1.2	1.8	2.9	1.8	2.7	3.5	1.7	2.3	4.4	0.5	0.9	4.0
Eggplant	1.8	1.6	1.6	1.3	1.3	1.2	1.1	0.9	0.4	0.5	0.8	1.2
GLV	1.3	1.7	1.6	0.9	0.9	1.1	0.8	0.6	0.5	4.8	6.1	7.4
Other veg	1.4	2.0	2.3	5.6	3.3	3.8	5.2	3.8	2.5	2.5	1.3	0.6
Number of households	724	1151	619	725	1189	486	1550	642	120	1425	836	249
						SOUTH						
Food groups	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
Fruit	9.3	13.2	19.7	21.1	21.8	24.5	27.2	33.6	41.0	19.1	20.9	27.7
Okra	8.6	6.4	4.7	11.4	8.9	5.9	8.2	6.4	5.7	11.8	8.1	5.8
Onion	20.4	17.0	15.9	14.8	13.1	12.0	15.3	13.3	10.8	18.5	18.4	15.3
Pepper	23.2	23.4	21.4	17.0	17.4	17.6	16.0	14.7	12.0	10.9	13.0	11.0
Tomato (Fresh)	19.8	22.6	20.7	15.0	19.0	25.7	22.9	22.1	19.9	15.2	17.6	18.4
Tomato paste	10.3	9.6	9.6	7.1	7.5	5.3	5.1	5.6	6.3	6.8	7.5	7.4
Potato	0.0	0.2	0.2	0.2	0.3	0.5	0.2	0.5	0.4	0.1	0.2	0.2
Eggplant	2.1	2.2	2.2	2.0	1.7	1.7	1.3	1.6	2.2	1.0	1.2	1.6
GLV	2.2	1.4	1.2	2.4	1.0	0.7	0.1	0.1	0.1	14.2	12.0	11.8
Other veg	4.0	4.1	4.3	9.1	9.3	6.1	3.7	2.1	1.7	2.4	1.1	0.7
Number of households	484	980	1029	348	911	1051	885	956	427	412	1232	821

**Terciles are created based on average per capita daily total expenditure of a household in both seasons (pre-harvest and post harvest : Tercile 1: less than or equal to $1.9, Tercile 2: between $1.9 and $4, Tercile 3: greater than $4.

Table 1.9: Median expenditure elasticities by region

	North			South		
Food groups	All	Urban	Rural	All	Urban	Rural
Fruit	2.23	2.00	2.31	1.20	1.19	1.21
Okra	0.99	0.98	0.99	0.84	0.84	0.84
Onion	0.77	0.74	0.78	0.65	0.66	0.64
Pepper	1.10	0.94	1.15	0.83	0.83	0.84
Tomato (Fresh)	1.01	0.94	1.04	0.87	0.86	0.88
Tomato paste**				1.15	1.15	1.16
Other veg*	1.29	1.25	1.31	1.11	1.11	1.10
Cereals	0.88	0.85	0.89	0.77	0.77	0.76
Tubers	1.42	1.36	1.44	0.94	0.91	0.97
Pulses	1.22	1.13	1.25	0.79	0.77	0.81
Oils	0.86	0.86	0.86	0.70	0.71	0.70
Animal proteins	1.58	1.39	1.65	0.98	0.95	1.01
Dairy	1.87	1.80	1.90	1.90	1.77	2.06
Other foods	1.04	1.01	1.05	1.23	1.22	1.25

*For elasticity estimations, this category includes canned vegetables as well as eggplant, potato, GLVs due to the low consumption in terms of share of households.
**As the share of consumers is low for the North, we do not report these elasticities.

Table 1.10: Median expenditure elasticities by income terciles (proxied by total expenditure)**

	North			South		
Food groups	T1	T2	T3	T1	T2	T3
Fruit	2.45	2.16	1.88	1.28	1.21	1.14
Okra	1.02	0.98	0.95	0.83	0.85	0.84
Onion	0.75	0.77	0.83	0.63	0.63	0.69
Pepper	1.28	1.00	0.94	0.82	0.85	0.83
Tomato (Fresh)	1.08	0.98	0.95	0.95	0.87	0.83
Tomato paste**				1.30	1.16	1.08
Other veg*	1.27	1.31	1.30	1.22	1.12	1.03
Cereals	0.90	0.86	0.80	0.81	0.77	0.73
Tubers	1.54	1.34	1.37	1.05	0.95	0.83
Pulses	1.34	1.17	1.08	0.90	0.80	0.70
Oils	0.86	0.86	0.85	0.69	0.68	0.74
Animal proteins	1.89	1.44	1.21	1.07	0.99	0.91
Dairy	1.93	1.89	1.68	2.53	1.98	1.52
Other foods	1.06	1.04	1.01	1.32	1.27	1.14

* For elasticity estimations, this category includes canned vegetables as well as eggplant, potato, GLVs due to the low consumption in terms of share of households.
**As the share of consumers is low for the North, we do not report these elasticities.

Table 1.11: Median own- and cross-price elasticities

NORTH

	Fruit	Other veg*	Okra	Onion	Pepper	Tomato (Fresh)	Tomato paste**	Cereals	Tubers	Pulses	Oils	Animal proteins	Dairy	Other foods
Fruit	**-1.06**	0.06	0.11	-0.05	0.02	0.00		-0.01	-0.15	-0.07	-0.06	0.03	0.23	-0.05
Other veg*	-0.14	**-0.82**	-0.04	-0.10	0.00	-0.08		0.00	0.03	-0.01	-0.02	-0.05	-0.04	-0.06
Okra	0.02	0.17	**-0.85**	0.03	0.10	0.07		-0.02	0.01	0.01	0.03	0.03	0.14	-0.01
Onion	0.12	0.39	-0.03	**-0.93**	-0.08	-0.03		-0.04	0.21	-0.03	-0.02	0.01	0.12	0.01
Pepper	-0.10	0.04	0.05	-0.07	**-0.79**	-0.09		-0.01	-0.06	-0.01	-0.02	0.01	-0.10	-0.06
Tomato (Fresh)	0.10	0.05	0.01	0.05	0.03	**-0.86**		0.00	0.03	0.02	0.01	-0.06	-0.04	0.00
Tomato paste**														
Cereals	0.26	0.04	0.04	-0.16	-0.12	-0.37		**-0.83**	0.27	-0.13	0.09	-0.16	-0.38	-0.12
Tubers	0.00	-0.09	-0.07	-0.02	-0.03	0.17		-0.04	**-0.88**	0.00	0.00	0.05	-0.13	0.01
Pulses	0.23	0.13	0.11	0.20	-0.04	0.09		0.00	-0.17	**-0.77**	-0.06	0.07	0.23	0.04
Oils	0.03	-0.08	-0.10	0.11	-0.07	0.05		-0.06	-0.15	-0.15	**-0.69**	0.08	-0.36	0.16
Animal proteins	-0.88	-0.02	-0.41	-0.11	-0.08	0.01		-0.06	0.19	-0.16	-0.01	**-0.84**	-0.21	-0.11
Dairy	-0.23	-0.04	-0.06	-0.02	0.10	0.06		0.01	0.02	-0.07	0.00	-0.05	**-0.92**	-0.11
Other foods	-0.35	0.24	-0.11	-0.10	-0.51	-0.13		-0.01	-0.11	0.19	-0.07	-0.10	-0.15	**-1.06**

SOUTH

	Fruit	Other veg*	Okra	Onion	Pepper	Tomato (Fresh)	Tomato paste**	Cereals	Tubers	Pulses	Oils	Animal proteins	Dairy	Other foods
Fruit	**-0.79**	0.12	-0.10	0.03	-0.05	0.02	0.00	0.02	-0.01	0.01	0.01	-0.03	0.01	-0.03
Other veg*	-0.09	**-0.99**	-0.16	-0.03	0.05	-0.12	0.03	-0.02	0.06	-0.05	0.03	0.06	0.13	0.05
Okra	-0.02	0.09	**-0.83**	0.07	0.08	0.10	0.05	0.04	-0.11	0.16	0.09	0.03	-0.11	-0.10
Onion	-0.12	0.29	0.01	**-0.78**	-0.19	-0.23	0.05	-0.03	0.07	-0.05	0.12	-0.02	-0.11	0.15
Pepper	-0.05	-0.01	-0.19	-0.06	**-0.77**	-0.01	-0.08	-0.03	0.06	-0.04	-0.01	0.01	-0.03	-0.11
Tomato (Fresh)	0.02	0.19	-0.01	0.10	0.15	**-0.91**	0.00	-0.03	0.04	-0.08	-0.06	-0.04	-0.10	0.04
Tomato paste **	0.01	-0.10	-0.03	0.07	0.06	0.04	**-0.77**	0.04	0.07	0.05	0.09	0.08	-0.01	0.05
Cereals	0.39	0.06	-0.13	0.00	-0.08	0.26	-0.12	**-0.87**	0.41	-0.26	0.30	-0.11	-0.39	0.51
Tubers	-0.15	-0.09	0.17	0.02	-0.01	-0.05	-0.15	-0.07	**-0.63**	-0.04	0.05	0.03	-0.22	-0.04

Table 1.11 (cont'd)

Pulses	-0.12	0.15	0.09	-0.07	-0.02	-0.03	-0.02	-0.06	0.18	**-0.76**	0.08	-0.01	0.15	0.33
Oils	0.22	-0.09	0.05	-0.16	-0.13	-0.40	-0.09	0.12	-0.02	0.03	**-0.45**	-0.10	-0.02	0.23
Animal proteins	-0.01	-0.12	-0.11	-0.17	0.02	0.05	-0.07	-0.01	0.05	-0.04	-0.26	**-0.75**	0.06	-0.05
Dairy	-0.09	0.14	0.22	0.02	-0.01	0.03	-0.24	0.05	0.23	-0.04	0.07	-0.06	**-0.81**	0.10
Other foods	-0.19	0.25	-0.03	-0.13	-0.04	-0.05	-0.18	-0.05	0.15	-0.06	-0.14	-0.11	0.00	**-0.96**

* For elasticity estimations, this category includes canned vegetables as well as eggplant, potato, GLVs due to the low consumption in terms of share of households.

**As the share of consumers is low for the North, we do not report these elasticities

CHAPTER 2: HETEROGENEOUS CONSUMPTION PATTERNS OF ANIMAL PROTEINS IN NIGERIA: A PANEL DATA ANALYSIS

2.1. Introduction

Global demand for animal proteins including meat, seafood, and dairy across the world has tremendously increased over the last several decades. This transformation is occurring in stages at different times in various parts of the world and is associated with rise in incomes and increasing population. During the first stage, consistent with Bennett's law (Bennett, 1941), as incomes rise, dietary patterns tend to shift from reliance on non-starchy staples towards incorporating more nutrient-dense foods such as animal proteins. As incomes continue to rise further, the second stage called "peak meat" or the stage of stagnation is reached after which per capita consumption begins to decline (Spiller & Nitzko 2015, Vranken et al. 2014). High income countries in North America and Europe, having the highest per capita consumption of animal proteins in the world, are beginning to enter the second stage of transformation (Parlasca and Qaim, 2022). On the other hand, majority of the world population, particularly in middle and low-income countries, is still in the first stage of dietary transformation and would continue to drive the increase in meat demand (Desiere et al. 2018, Gouel & Guimbard 2019). The most dramatic increase in the per capita animal protein consumption has taken place in Latin America, Africa, and Asia after 1990s (Parlasca and Qaim, 2022). While the consumption levels of animal proteins are nearly comparable to developed countries in Latin America, those in Sub-Saharan Africa (SSA) are much lower than other developing regions. Thus, SSA has only just entered the first stage of dietary transformation with huge potential for growth in the coming decades as incomes increase and population goes up.

Such increasing demand has led to a significant domestic supply response that has triggered the so-called "livestock revolution" (Delgado, 2003; Narrod et al., 2008). For centuries, SSA's animal production has been dominated by cattle (beef) and seafood. While cattle production was extensive and transhumant (nomadic grazing) by pastoralists along scrub and grass areas near deserts, most cattle were raised for subsistence, milking, eating old animals, and bleeding for food. Fish farming was largely unknown, and seafood mainly came from fishing. Also, goats and pigs were raised near or in the rural compound. Pino (1970) estimated that cattle production in "tropical Africa" was 300 million head and formed about 15% of total agricultural output and 5% of the GDP; the livestock population was estimated at 124 million cattle, 98 million sheep, 80 million goats, and 12 million horses, mules, and asses. So even in 1966 the leading non-fish animal product was cattle, four times more numerous than small ruminants.

By 2020, however, cattle and small ruminants in SSA were estimated to be about 1.3 billion (up 4.3 fold from the 1970 number 50 years earlier). There were about 370 million cattle (only 2.5 times the 1970 number); goats and sheep numbered 910 million, up 7-fold from 1970. Pigs numbered just 44 million, indicating they are still minor. Chickens had not been counted in the 1970 publication (probably because seen as a minor source of meat and just a few eggs per rural household), but by 2020 were more than 2 billion[5].

Even in terms of quantity of meat (in million tons), according to FAOSTAT data, Africa's meat production tripled between 1970 and 2020 as can be seen in Figure 2.1. Over these decades, beef production increased by about 3 times and that of seafood increased by 4 times. Poultry production, on the contrary, has increased by about 20 times. In fact, in 2020 poultry production in absolute terms at 6.7 million tonnes was higher than that of the total beef production (6.2 million tonnes).

The rapid increase in animal production (especially cattle) has raised concerns about its sustainability and contribution to climate change through its resource-intensive nature and greenhouse gas emissions. As demand for animal protein continues to rise, promoting sustainable growth in animal production becomes crucial. One possible solution is to promote poultry and seafood, which have lower greenhouse gas emissions compared to beef. Thus, understanding consumer preferences and demands for different types of animal proteins is essential in identifying sustainable options. Given the perishability of meat and the lack of processing units and cold storages in Africa, having a demand-driven value chain can improve efficiency and strengthen the entire process. Therefore, detailed information on consumer demand is essential for developing and implementing effective strategies towards sustainable animal production.

The literature on food demand, mostly focusing on nutrition rather than markets and food systems, has examined the demand for animal proteins as a foodgroup. However, a few studies have conducted a disaggregated analysis of animal protein demand (Aborisade and Carpio, 2017; Desiere et al., 2018; Zhao and Staatz, 2017). These studies use cross-sectional data that do not allow demand analysis over time and mostly focus on intercountry analysis rather than focusing on different regions within a country. This is a glaring gap in the literature as no study has analyzed consumer demand for different food groups at a disaggregated level over spatial categories such as agroecological zones as well as regions with varying levels of development.

[5] https://www.statista.com/statistics/1290023/livestock-population-in-africa

Also, no study has looked at substitutability across different types of animal proteins and between animal proteins and other food groups. Our study aims to contribute to this goal by conducting a disaggregated demand analysis for different types of animal proteins with Nigeria as a case.

Nigeria presents an interesting case because it is the most populous country with the highest GDP in Africa. Rising incomes and urbanization have increased the demand for food and its composition has been changing with the diversification of diets. As predicted by Bennett's law, the share of food expenditures on starchy staples are being replaced by other products including animal proteins (Tschirley et al., 2015; Muyanga et al., 2019). Large and positive expenditure elasticities for animal proteins have been noted in Nigeria (Zhou and Staatz, 2017).

In response to the observed gaps in the literature noted earlier, this paper analyzes the consumption patterns, food expenditure, and price elasticities for different sources of animal proteins in Nigeria using data from a nationally representative panel survey spanning almost a decade. To account for potential variation in employment, market access and use, lifestyle and preferences, we stratify our analysis by urban and rural areas. We also distinguish between Nigeria's richer South and the poorer North to account for economic and agroecological variation in demand for and access to animal-sourced foods. Also, using panel data allows us track changes over time and control for time invariant factors in order to estimate consumer demand. This has not been done before particularly at a disaggregated level in Africa.

Thus, this paper contributes to the literature in the following ways. First, our demand analysis includes different types of animal-protein foods including eggs and poultry meat. Second, we conduct spatial analysis to examine how demand patterns for products vary over poor and rich regions of urban and rural areas. Third, using panel data for demand estimation allows us to understand how demand is evolving over time.

2.2. Changes in production patterns in Nigeria

In Nigeria, the consumption of animal proteins has been a crucial part of the food budget, with the food budget share of 20% in urban areas and 15% in rural areas (Liverpool-Tasie, 2016). Additionally, it is projected that animal protein consumption in Nigeria will increase by 75% in the next decade, indicating a significant demand for animal proteins (FAO, 2019). This surge in demand has led to a transformative shift in production patterns, which could have significant implications for food systems, nutrition, and the environment.

For example, in Nigeria cattle have been the main source of animal protein for an extended period, similarly to other sub-Saharan African countries. With rising demand, between 1981 and 2012, the population of Nigeria's cattle more than doubled from approximately 9.2 million to 20 million, making it the one of largest cattle population in the world (Kubkomawa, 2017; FAO, 2020). However, cattle rearing is a resource-intensive activity that requires a considerable amount of water and abundant grazing grounds. Over the last decade, in the Northern parts of Nigeria where cattle production primarily takes place, there has been a significant reduction in mean rainfall which has resulted in desertification and thus stagnation of beef production.

On the contrary, poultry production took off rapidly in Nigeria as in many developing countries (Liverpool-Tasie et al., 2017). In Nigeria chicken and egg outputs grew by 220% and 320% respectively between 1980 and 2019. This has been possible due to low resource-intensive nature of poultry production and its short production cycle (Heise et al., 2015). Also, Nigeria's fish continues to dominate total production in Nigeria.

Thus, it is important to study demand for animal proteins holistically to guide increasing its production sustainably. Understanding consumer preferences is essential to create demand-driven and efficient value chains. For example, despite such increases in production of poultry and seafood, Nigeria still relies heavily on beef imports. While beef production in Nigeria was about 0.33 million tonnes (cattle meat) in 2018 (FAO, 2018), our analysis of LSMS 2018 consumption data shows that domestic demand for beef was about 1 million tonnes. This suggests that beef demand far exceeds its production capacity. Moreover, although the poultry subsector is expanding rapidly, per capita consumption numbers for Nigeria are very low as compared to other regions in Africa.

Thus, in this paper, we study the demand for different types of animal proteins across regions differing in levels of development, urban vs rural areas, and income groups.

2.3. Data

Our study uses data on food consumption and household characteristics in the Nigeria Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA) program collected by the World Bank. This nationally representative survey covers urban and rural areas of six geopolitical zones in Nigeria, thus capturing heterogeneity in agroecology and demography across the richer South and the poorer North of Nigeria. We use four waves of this data collected in 2010/11, 2011/12, 2015/16, 2018/19. Each wave includes about 5000 unique households surveyed twice a year during post-planting and post-harvest seasons. Collection of data twice a year in different seasons helps capture any seasonal heterogeneity in consumption. The first three waves generate a panel as the same households were interviewed in each round of data collection.

The household food consumption module collects quantities of various food items consumed in the preceding 7 days of the interview. We aggregate the food items into 12 food-at-home groups including different types of animal proteins and other food groups. The 12 categories include six sources of animal proteins such as beef, seafood, poultry meat, eggs, milk[6], and other meats[7] (mutton, pork, goat, wild meat, others), along with 5 other food groups namely cereals, tubers, pulses, oils, fruit, vegetables and other foods.

The total quantities of products consumed includes purchases, home production, and gifts. We clean top quantity outliers by winsorizing per capita quantities of each item in each household at the 99th percentile. As item-level prices are not available in the data, we calculate prices by dividing total expenditure on purchased items divided by quantity purchased. Whenever food items are not purchased by households, unit prices are missing. We impute such prices using median unit values at the item, unit, and location level starting with the most disaggregated location specification (EA). Further, prices higher than the median are capped at median prices at the item, unit, and location level. Using these prices we then calculate total value of food items consumed by a household by multiplying price with total quantity (consumed from all sources). Finally we convert nominal prices and expenditure values into real values using Nigeria's consumer price index (CPI) for each survey year keeping 2010 as the base year.

A method used to classify households based on income involves dividing them into three groups, taking into account their total expenditures on food and non-food items. This provides a rough estimation of their income levels. The first group consists of the poorest households (Tercile 1), whose daily per capita expenditure is less than $1.9 in constant dollars adjusted for purchasing power parity (PPP) as of 2011. The second group (Tercile 2), includes households with daily per capita PPP expenditure greater than $1.9 but less than $4, while the third group comprises the wealthiest households with per capita expenditures above $4 per day (Tercile 3).

[6] Of all dairy products, only milk (fresh and packaged) is a source of proteins. Hence, other dairy products are categorized as Other foods.
[7] The Small Ruminants category primarily includes mutton, goat, and pork along with a small share of wild game meat and other meats.

2.4. Data descriptives and consumption patterns

Table 2.1 shows real prices for different FV items and other food groups. We will refer to this table throughout our analysis.

Table 2.2 presents the share of households consuming different types of animal proteins by regions and over time in Nigeria. Several findings emerge. First, animal proteins are common in the diet, and this holds true for both rural and urban households and across regions varying in economic development. About 90% of the households in the North and almost all households in the South consume some form of animal protein in a typical week and the share has remained nearly constant between 2010/11 and 2018/19.

Second, as per 2018/19 survey, while seafood is the most popular form of animal proteins in both the regions, it is consumed more widely in the South (97% of households) than in the North (57% of households). Seafood is followed by beef in terms of popularity with the share of households being 48% in the North and 67% in the South during that year. Further, milk (fresh milk and packaged drinks combined) is consumed by about 33% and 63% of the households in the North and South respectively. Furthermore, compared to seafood, beef, and dairy, poultry (both eggs and meat) are relatively less popular in both the regions. In the North, eggs and poultry meat are consumed by 22% and 21% of the households respectively in a typical week. In the South, while poultry meat is consumed by only 21% of the households, 49% consumed eggs. Additionally, the share of households consuming small ruminants is low at 22% in the North and 12% in the South.

Third, in the North, the share of beef-consuming households has consistently declined from 61% to 48% between 2010/11 and 2018/19. While the share of seafood-consuming households remained constant at 64% between 2010/11 and 2015/16, it declined slightly to 57% in 2018/19. Milk consumption, on the other hand, has remained constant with the share of households at about 33%. Further, poultry-consuming households declined from 18% to 11% between 2010/11 and 2015/16 but increased to 21% in 2018/19. On the contrary, egg consumption has increased consistently over time and almost doubled from 12% in 2010/11 to 22% in 2018/19.

However, unlike in the North, animal protein consumption in the South increased over time for all items except for seafood (having high share of households across all years) and small ruminants (for which the share of households declined from 18% to 12% over the decade). Contrary to the North where beef consumption declined, the share of households for beef increased from 62% to 67% in the South between 2010/11 and 2018/19. Furthermore, the share of households consuming milk more than doubled from 31% to 63%. Further, poultry consumption (both meat and eggs), similar to the North, has been expanding with the increase in the share of egg-consuming households (from 32% to 49%) far exceeding the increase in the share of households consuming poultry meat (17% to 21%) over the last decade.

Fourth, we note interesting differences in urban and rural areas of North and South. In the North, the share of households consuming beef, seafood, and dairy is higher in the urban areas (68%, 69%, and 47% respectively) than that in the rural areas (43%, 53%, and 29% respectively). Further, the share of egg-consuming households in the urban areas (36%) is almost twice that of the rural areas (19%). On the other hand, poultry meat is consumed by only 16% of the households in the urban areas as compared to 22% in the rural areas. Additionally, the share of households consuming small ruminants is nearly the same at 22% in both urban and rural areas of the North.

In the South, seafood is an important item and is consumed by almost all households in a typical week in both urban and rural areas. Further, beef and dairy are consumed by a higher share of households in the urban areas (73% and 65% respectively) than those in the rural areas (63% and 61% respectively). Similarly, eggs and poultry meat have higher consumption in the urban areas (with the share of households at 56% and 28% respectively) than in the rural areas (45% and 17% respectively). On the contrary, small ruminants are consumed by twice the share of households in the rural areas (16%) than in the urban areas (7%).

Fifth, in terms of trends over time across urban and rural areas, two important points stand out. Though the share of egg-consuming households is higher among urban households in both North and South, there has been much more rapid growth in rural consumption. In the rural North, the share of households consuming eggs in a typical week more than tripled (from 7% in 2010/11 to 19% in 2018/19) while in the urban areas, it increased from 27% to 36% over the last decade. In the rural South, the share of households consuming eggs more than doubled (from 21% in 2010/11 to 45% in 2018/19) whereas it increased from 41% to 56% in the urban areas. Further, trends in milk consumption suggest that the share of households consuming milk in the North increased from 35% to 47% in the urban areas and remained almost constant in the rural areas. However, in the South, the share of milk-consuming households rose from 36% to 65% in the urban areas and from 26% to 61% in the rural areas.

Table 2.3 describes the share of households consuming different types of animal proteins and other food groups by per capita income groups (proxied by total expenditure on food and non-food items). First, as expected, in both North and South, consumption increases with income for all different types of animal proteins (except for seafood in the South).

As per the 2018/19 data, in the North, among the poorest households, the shares of households consuming seafood, beef, and milk (52%, 38%, and 25% respectively) are lower than that those in the richest group (62%, 78%, and 45% respectively). While consumption of poultry meat among the richest group (30%) is almost double that of the poorest group (16%), consumption of eggs is 5 times higher among the richest (51%) than the poorest (10%) group.

Even in the affluent South, consumption of animal proteins (besides seafood), is much more prevalent among the richer households as compared to the poorest. The shares of households consuming beef and milk are significantly higher (both at 74%) among the richest as compared to the poorest (46% and 35% respectively). Also, the consumption of poultry meat and eggs are higher by 4 times and 2.5 times respectively among the richest (with the share of households at 35% and 66% respectively) than the poorest (with the share of households at 8% and 26% respectively).

Second, in the North, despite their popularity, the share of households consuming beef, seafood, and milk only increased slightly or remained almost constant between 2010/11 and 2018/19 among the poorest. On the other hand, the share of households consuming eggs increased by 5 times from 2% to 10% while those consuming poultry meat increased from 10% to 16% over the last decade. Among the richest (tercile1), the share of households consuming beef, milk, and poultry meat have remained almost constant over the last decade and that for seafood declined from 77% to 62%. The share of eggs-consuming households, however, more than doubled from 28% to 51% over the decade. Among the middle group (tercile 2), we notice a significant shift in consumption patterns over time for all types of animal proteins except for seafood and small ruminants (with constant consumption). While the share of beef-consuming households dropped from 67% to 56%, there has been a significant increase in the shares of households consuming milk (31% to 43%), poultry meat (18% to 27%), and eggs (9% to 35%) between 2010/11 and 2018/19.

Third, among the poorest households in the South, beef (other than seafood) was the only important source of animal protein in 2010/11. Between 2010/11 and 2018/19, the share of beef-consuming households rose from 33% to 46%. Further, the share of milk-consuming households dramatically increased by 7 times from 5% to 35% over the last decade. Similar to the North, poultry meat consumption although low doubled (from 4% to 8% share of households) and that of eggs tripled (from 9% to 26%) over the decade. Even among the middle and the richest groups (G2 and G3), the shares of households for all types of animal proteins increased over time (except for seafood which was already very high).

Table 2.4 shows per capital annual consumption (in kg) for different kinds of animal proteins and reveals three striking points. First, as expected, per capita annual consumption of animal proteins is higher in the affluent South than in the poorer North. In 2018/19 an average person in the South consumed about 32.2 kg of animal proteins in a year as opposed to only 13.8 kg in the North. Per capita annual consumption of seafood and beef (top 2 items in both the regions) in the South was at 19.9 kg and 7.1kg respectively, higher by a multiple of 3 and 2 than an average person in the North consuming 6.1 kg and 3.7 kg of seafood and beef respectively in 2018/19. Poultry meat consumption was low at about 2.4 kg per person in a year in both North and South. Similarly, egg consumption was generally low but with annual per capita consumption in the South (1.9 kg) more than double the annual per capita consumption in the North (0.8 kg).

Second, we note that total per capita consumption of animal proteins has declined over time, particularly in the North. Overall, per capita consumption of animal protein in the North, significantly and consistently decreased by about 38% from 22.3kg in 2010/11 to 13.8kg in 2018/19. Among different sources of animal proteins, per capita consumption of beef declined by about 50% from 7.7kg to 3.7kg, that of seafood by about 31% from 8.9 kg to 6.1kg and milk by 47% from 4.8 liters and 2.5 liters. The per capita annual consumption of poultry meat has also declined from 2.4 kg to 1.8kg while egg consumption remained constant at 0.8kg. However, in the South, total per capita annual consumption has slightly declined from 35.1 kg to 32.2 kg over the decade but a closer look at the trend reveals that the drop in consumption levels happened between 2010/11 and 2012/14 but has in fact been increasing again between 2012/14 and 2018/19 (24.9 kg in 2012/14 and 32.2 kg in 2018/19). Between 2010/11 and 2018/19, the annual per capita consumption of beef, seafood, and poultry meat has remained almost constant or only slightly declined. On the other hand, per capita annual consumption of eggs increased by 26% from 1.5 kg to 1.9 kg.

Third, we note interesting differences in total meat consumption in urban and rural areas of North and South. In the North, as expected, overall per capita animal protein consumption is higher in urban areas (18.5 kg) than in rural areas (12.5 kg) according to the latest 2018/19 data. However, per capita consumption of milk is higher in rural areas at 2.7 liters as compared to urban areas (1.7 liters). This might reflect the consumption of fresh milk among rural populations engaged in livestock rearing. Interestingly, poultry meat consumption is at 1.8 kg in both areas of the North. On the contrary, in the South, there is hardly any difference in the per capita annual consumption of animal proteins in urban and rural areas (31.3 kg in urban areas and 32.9 kg in rural areas). The starkest difference is seen in the consumption of poultry meat and eggs where urban consumption far exceeds that in the rural areas. For example, annual per capita urban poultry meat consumption was 3.2 kg and that in rural areas was only 1.7 kg in 2018/19. For eggs, the consumption levels are at 2.4 kg and 1.6 kg in urban and rural South respectively.

Overall these results suggest that although there has been a rapid expansion in the share of households consuming various animal source foods across Nigeria, the per capita quantity consumed has not increased over time. In fact in many instances there has been a reduction in the per capita consumption with exception eggs particularly in the South.

Table 2.5 shows per capital annual consumption (in kg) for different kinds of animal proteins over time and regions across income levels and reveals six striking points. First, the total per capita annual consumption of animal proteins increases with income in both North and South. In the North, an average person among the poorest group and the richest group consumes about 6.8 kg and 37.2 kg of animal proteins respectively in a year in 2018/19. In the South, the total annual per capita consumption on an average is about 11.3 kg in the poorest group and about 48.4 kg in the richest group. This shows that the disparity in consumption of animal proteins (in terms per capita quantity) across income groups is quite dramatic with the per capita consumption among the richest group in the North (South) being 5 times (4 times) more than that of the poorest.

Second, in the North, even among the most widely consumed animal protein source (seafood), the per capita consumption level among the richest households (14.4 kg) is more than four times higher than that of the poorest households (~3.3 kg). For beef (the other main animal protein source) per capita consumption of the richest households in the North is about 8 times higher than that among the poorest households.

Third, even in the South, where consumption of animal proteins is well established, the differences in the average per capita consumption of animal-protein items across income groups are quite large. For example, per capita consumption of seafood among the richest households in the South (28kg) is 3 times that consumed by the poorest (8.4 kg) while beef quantities consumed by the richest (12.4kg) are 7 times more than that of the poorest households (1.6 kg).

Fourth, the contrast between the impoverished North and the affluent South becomes evident when we compare total per capita consumption of animal proteins by income groups – the average per capita consumption of the poorest in the South is 66% more than the poorest in the North while the richest in the South consumed 30% more than those in the North.

Fifth, the consumption of animal proteins per capita has decreased among all income brackets, with a greater reduction observed in the poorest households compared to the richest, in both North and South.

In the North, between 2010/11 and 2018/19, the per capita consumption of beef decreased from 14.1kg to 12.4 kg (about 12% reduction) for the richest group. However, for the poorest, beef quantities reduced by almost 36% from 2.5 kg to 1.6 kg over the same time period. While the average seafood per capita consumption levels have declined slightly by about 8% from 15.7 kg to 14.4 kg over the last decade for the richest, they have declined by almost 25% for the poorest (from 4.4 kg per capita in 2010/11 to 3.3 kg per capita in 2018/19). In contrast, a decline in the levels of milk consumption was higher among the richest households than among the poorest. For the richest group there has been a 73% decrease in per capita consumption of milk from 6.3 liters in 2010/11 to 1.7 liters in 2018/19 while the decline is lesser at 36% for the poorest (from 3.8 liters to 2.4 liters).

In the South, a similar pattern (of decline in per capita consumption) is observed across all income levels in seafood and milk. Per capita consumption of seafood reduced by 27% for the poorest households (from about 11.5 kg in 2010/11 to 8.4 kg in 2018/19) compared to almost negligible (6%) decline among the richest households (from 29.6kg in 2010/11 to 27.9 kg in 2018/19). For milk, the per capita consumption reduction is high among the richest (60%) from 3.5 liters in 2010/11 to 1.4 liters in 2018/19 as well as the poorest households (about 70% where per capita consumption declined from 2.1 liters in 2010/11 to 0.6 liters in 2018/19.

Sixth, the one animal-protein item where an increase in per capita consumption was noted is in poultry (eggs and meat) in both regions except for poultry meat in the North. In the South, poultry meat consumption increased by 33 % from 0.3 kg to 0.4 kg for the poorest households between 2010/2011 and 2018/19 and by 10 % (from 4.2 kg to 4.6 kg) for the richest households. An even more significant increase was seen for eggs where per capita consumption doubled from 0.2 kg to 0.4 kg for the poorest households and increased from 2.6 kg to 3.4 kg (30%) for the richest over the decade. In the North, poultry meat consumption slightly declined by 11% (from 0.9 kg to 0.8 kg) among the poorest and declined negligibly (2%) among the richest households. Eggs consumption, however, doubled from 0.1 kg to 0.2 kg among the poorest and increased by 34% (from 2.3 kg to 3.1 kg) among the richest.

Table 2.6 presents average shares of the animal-protein budget on different items by region and over time. Four key points emerge. First, the share of food budgets spent on animal proteins is 14.8% in the North and 24.7% in the South. In the North, of the total expenditure on animal proteins, 34.1% is spent on beef and about 28.3% on seafood. Together beef and seafood account for more than 60% of the animal protein budget on an average. In the South, seafood dominates animal protein budget accounting for 50.1% of the animal protein budget. The second most important animal protein in terms of budget shares is beef (27.9%). This pattern prevails for both rural and urban areas.

Second, the share of animal protein budgets spent on poultry meat and eggs is still low even though the rapid expansion of poultry has taken place in terms of consumer shares. Poultry meat accounts for about 13.8% of the animal protein budget in the North and 9.3% in the South. The share of animal protein budgets on eggs is still lower at 2.8% and 3.5% in the North and South respectively.

Third, in the North, a fair share of animal protein budget goes to small ruminants (13.3%) while it is negligible in the South at 3.4%. Further, the share of animal protein budgets on milk is low at 7.7% and 5.8% in both the regions.

Fourth, consistent with the observed decline in the consumption of beef over time, the budget share of beef in the North declined from its previous level at almost 40% in 2010/11 to 34% in 2018/19. This contrasts with the South where the budget share of beef has actually increased slightly from 25.3% to 27.9% between 2010/11 and 2018/19.

Fifth, we noted a decline in per capita consumption of poultry meat in the North while it remained constant in the South. However, the share of budget on poultry meat increased from 9.7% to 13.8% between 2010/11 and 2018/19 in the North, while it increased from 5.4% to 9.3%

in the South. A similar trend was observed in both urban and rural areas of North and South alike. Overall this highlights the growing importance of poultry meat in the diets of Nigerians.

Sixth, interestingly share of animal protein expenditure on poultry meat in rural North (15%) is higher than that in the urban areas (11%) suggesting that poultry meat consumption in the North dominates rural areas. This is due to the fact that per capita quantities of all items except poultry meat are lower in the rural North than in the urban North. We suspect this is due to predominance of backyard poultry farming around rural areas of the North.

Table 2.7 presents average shares of budgets on different animal proteins by region and over time across income groups. Three key points emerge. First, in the North, the dominance of beef and seafood in the animal-protein food budget prevails for all income groups. Together these two animal protein forms account for over 50% of the animal-protein food budget of the richest and poorest households. Beef accounts for the highest budget share for the richest households (about 45%) compared to 30% for the poorest households. Seafood accounts for 21% of animal-sourced food budgets for the richest households and 31% for the poorest.

Second, in the South, seafood dominates the animal-protein food budget generally, but particularly among the poor. In 2018/19 seafood alone accounts for over 65% of the animal-sourced food budget for the poorest households. This compared to 45% for the richest households in the same year. Beef and seafood accounted for almost 75% of the animal-sourced food budget of the poorest households in the South compared to 63% among the richest.

Third, the shares of animal-protein budgets spent on seafood decline with income in both North and South while it increases with income for all other items (except small ruminants in both regions and milk in the North). This indicates that the poorest households depend mostly on seafood to meet their demand for animal proteins and gradually diversify their diets with other types of animal protein as their income increases.

2.5. Methodology

2.5.1. Model

We choose EASI (Exact Affine Stone Index) functional form over other widely used forms such as Almost Ideal Demand System (AIDS) for several reasons. First, the EASI allows Engel curves to follow a flexible form and is more appropriate in the context of developing countries where income ranges are wide and food expenditure elasticities vary significantly with household income. Second, consistent with utility theory, the two-way EASI model allows

Hicksian demand to change with total expenditures by interacting log prices with real expenditures. The AID model, however, allows only Marshallian demand to change with total expenditures through the income effect in the Slutsky equation.

The two-way approximate EASI demand system is specified as

$$w_{hit}^{*} = \sum_{j=1}^{J} a_{ij} ln\, p_{hjt} + \sum_{j=1}^{J} a_{ijy} y_{ht} ln\, p_{hjt} + \sum_{r=1}^{L} b_{ir} y_{ht}^{r} + \sum_{k=1}^{K} v_{ik}\, z_{hkt} + u_{hit} - - - - (1)$$

$$h = 1, \ldots, H;\ i = 1, \ldots, J-1;\ t = 1, 2, 3, 4, 5, 6$$

where w_{hit}^{*} is the latent budget share on the i th category for household h at time t; p_{hjt} is the price index for household h and category j; J is the number of demand categories and equals 13 FAH categories (12 distinct categories and other foods as a numeraire), h denotes the household id and H is the total number of households; y_h is the real total household expenditure; L is the highest degree of total expenditure polynomial to be determined by statistical tests, the $z_{hkt}'s$ are K exogenous demand shifters including a constant, the a_{ij}, a_{ijy} , b_{ir}, v_{ik} terms are parameters; u_{hi} is the regression residual. The latent budget share w_{hit}^{*} is associated with observed budget share w_{hit} by $w_{hit} \equiv \max\{0, w_{hit}^{*}\}$, where w_{hit} is calculated as the category expenditure divided by household food expenditure. Following Lewbel and Pendakur (2009), we construct the Stone price-deflated household expenditure $y_{ht} = \ln x_{ht} - \sum_{j=1}^{J} w_{hjt} ln\, p_{hjt}$ where x_{ht} is total nominal household expenditures on food. Further, we also include interactions between real total household food expenditure and log prices thus allowing Hicksian demand to vary with income.

Moreover, we include the vector of demand shifters, z_{hkt}, to control for observed taste heterogeneity among households. This vector, in addition to a constant, includes household head age, household size, and binary variables for education, gender, and areas (urban vs rural). We log and demean continuous variables in our analysis.

Furthermore, we exploit the panel structure of our data to account for time-invariant unobserved heterogeneity among households using correlated random effects specification (see Meyerhoefer et al. (2005)). The correlated random effects are specified by household level means across all survey rounds of (1) log prices for each foodgroup (2) interactions between log prices and real household food expenditure. These effects are included as additional demand shifters in the vector z_{hkt} in equation (1). Thus, our model with household level correlated random effects specification includes additional 24 demand shifters due to inclusion of mean log price and mean log price- real expenditure interactions for 11 food categories and the numeraire (other foods).

2.5.2. Econometric approach

We use a Tobit model to characterize censoring. We use the Tobit estimator over Shonkwiler and Yen for the following reasons. First, Shonkwiler and Yen develop an improved two-step approach that is general enough to model infrequency of purchase errors as well as other processes generating zero expenditures. However, its application to corner solutions has been criticized as it cannot account for the role of reservation prices (Arndt et al 1999). Second, all methods including Shonkwiler and Yen (1999) and other improvements were designed for cross-sectional data and thus has limited ability to account for preference heterogeneity. Therefore we use the Tobit estimator developed by Perali and Chavas (2000) for cross-sectional data and further extended to panel data by Meyerhoeffer et al (2005) and Kasteridis et al (2011). To estimate the Tobit demand system from equation (1) we use the extended Amemiya's Generalized Least Squares (AGLS) estimator (Zhen et al., 2014).

We address two potential sources of endogeneity. First, ln xh is deflated by a Stone price index and this introduces budget shares into log real total expenditure yh . We correct this endogeneity by instrumenting each household specific Stone price index with a modified index which deflates expenditures by the sample-average budget share for foodgroup j (Zhen et al., 2014; McCullough et al., 2022)

Second, prices could be endogenous. Particularly, endogeneity arises when calculating unit item prices from unit values. This is because of omitted variables bias that may occur if unobserved taste preferences drive consumers to choose a replace an item with another item in the food category in the presence of higher prices, thus making unit demand endogenous. We thus address this issue by constructing Fisher Ideal Price Indexes at food group level for each household following Zhen et al. (2011). The Fisher Ideal Price Index gives a second-order approximation to a linear expenditure function and hence addresses unit value bias due to substitution between items within a foodgroup (Diewert;1976; McCullough 2022). Therefore, the Fisher Price Index for household h and foodgroup j in time period t is given by

$$p_{hjt} = \sqrt{\frac{\sum p_{kh} q_{k0}}{\sum p_{k0} q_{k0}} \frac{\sum p_{kh} q_{kh}}{\sum p_{k0} q_{kh}}} - - - -(2)$$

Where p_{kh} and q_{kh} are unit price and quantity, respectively, of food item k in food group j consumed by household h in time period t; p_{k0} and q_{k0} are base unit price and base quantities respectively, and are calculated as average values for item k across all households in time period t.

However, consumers may substitute lower quality items in the presence of higher prices. Thus using unit values to estimate demand without accounting for quality introduces a unit value bias (Cox and Wohlgenant 1986; Deaton 1988). Moreover, unit value bias may occur when some households having a preference for certain items engage in price search and are able to get lower prices for identical items. Using Fisher Price Ideal Index does not account for such within-item quality substitutions and price search behavior. We address these sources of endogeneity by creating instrumental variables for prices using prices of neighboring households (Hausman 1997). We generate a price instrument for each price index, p_{hjt}, by calculating average price index of all households in each round and EA except household h. The identifying assumption that household level demand shocks are uncorrelated with those of its neighbors may not always hold. Nevertheless, use of household level correlated random effects may help to strengthen this assumption (McCullough, 2022).

As culture and income significantly differ across the North and South Nigeria, the two regions vary on several characteristics including food choices. We exploit this heterogeneity in regions by estimating equation (1) separately for the two regions. We report median elasticities by in North and South by area (urban vs rural) and income terciles.

2.6. Regression Results

As noted above, we estimate the system of $J - 1$ (where J is the number of food groups) Tobit equations separately for the North and the South using the extended AGLS. For both the estimations we determined the optimal order of polynomial on real total food expenditure by sequentially increasing L from 1 to 4 and then testing the joint significance of b_{iL} coefficients by minimum distance. We restrict the value of L to 4 as higher order polynomials could cause multicollinearity. We conduct the test without imposing the conditions of homogeneity and symmetry on the demand system as this would have become a joint test of the coefficients and the restrictions. The null hypothesis for the test is that y_h^L can be excluded from the demand system, and the test statistic is asymptotically distributed as $\chi^2(J - 1)$. For both the models, we conclude that L = 4 is the optimal degree of the polynomial.

Also, we tested for the joint significance of the coefficients on the interaction between log prices and income a_{ijy} without imposing the economic restrictions of symmetry and homogeneity.

We estimate expenditure and price elasticities for different food groups. Table 2.8 presents median uncompensated expenditure elasticities for different food groups and sources of animal proteins for the North and the South.

First, as expected, all types of animal proteins are normal goods i.e. as income increases, Nigerians consume more of all animal proteins. Moreover, all sources of animal proteins are luxury goods in both North and South except for seafood in the South. This means that a 1% increase in income increases consumption by more than 1% for all items (except for seafood in the South).

Second, in the North, although all items are luxury goods, the lowest elasticity of 1.38 is seen for seafood. Coupled with highest share of consumers for seafood and high per capita consumption, expenditure elasticity greater than 1 indicates that seafood is the most important form of animal proteins for the poorer North and its consumption will continue to increase disproportionately with income. Further, beef is another important type of animal protein with positive and large expenditure elasticity of 2.01 suggesting that the demand for beef will continue to increase rapidly with the rise in income. The highest expenditure elasticities are noted for poultry eggs (2.77) followed by poultry meat (3.79). This shows that even though poultry is gaining popularity and expanding rapidly, poultry items are still a luxury and have not yet become a daily part of diets. Yet, this also indicates that increasing incomes may lead to an increased demand for poultry.

Third, in the South, seafood has the lowest expenditure elasticity of 0.74. Large share of housholds, high per capita consumption levels, and low expenditure elasticity suggest that seafood is a necessity and thus an integral part of diets in South Nigeria. Apart from seafood, all other types of animal proteins are a luxury in the South similar to the North. Among luxury items, beef has the lowest expenditure elasticity of 1.44. Further, similar to the North, we note high expenditure elasticities for 2.23 and 3.18 for eggs and poultry meat respectively.

Fourth, expenditure elasticities in the North are higher for all types of animal proteins than the South except for milk. Although a luxury in both the regions, expenditure elasticity of milk is 2.36 in the South and 1.78 in the North. This might be due to availability of fresh milk in the

North but that of more expensive packaged milk in the South (as can be seen from prices shown in Table 1.1) making it more of a luxury item in the South.

Fifth, as expected, expenditure elasticities for all items in the urban areas are lower than those in rural areas of both regions. One exception to this observation is seafood in the South. Seafood has low expenditure elasticity of 0.74 in urban as well as rural areas of the South. This reiterates the dominance of seafood consumption in the diets of South Nigerians.

Table 2.9 presents expenditure elasticities by income groups. First, as expected, expenditure elasticity decreases with income for all items in both the regions except for seafood in the South. The expenditure elasticity for seafood for the lowest income group is 0.67 and that for the richest group is 0.80. Such low elasticities together with high consumption levels (as seen earlier) indicates that seafood is a necessity across all income groups in the South. However, the richest group may have a preference for expensive types of seafood (fresh and imported), which increases their expenditure on fish and thus exhibits slightly higher elasticity.

Second, all sources of animal proteins are a luxury across income groups in both the regions (with the exception of seafood in the South which is a necessity across income levels). Even the most popular items (seafood in the North and beef in North and South) exhibit high income elasticities across all income groups. While the expenditure elasticities of seafood in the North are 1.68 and 1.11 for the richest and poorest households respectively, those for beef are 2.67 and 1.28 respectively. Even in the South, beef expenditure elasticities are positive and high at 2.19 and 1.11 for the richest and poorest respectively.

Third, while we notice that the elasticity estimates are significantly higher for the poorest households in North and South (except for seafood in the South), the highest difference in elasticities is for eggs and poultry meat. The poorest households in the North and South have poultry meat elasticity of 4.49 and 4.21 respectively, and the richest households have 2.72 and 2.40 respectively. Also for eggs, the elasticity levels are 3.13 and 2.76 for the poorest households in North and South respectively, and 2.25 and 1.62 respectively for the richest group. Such high elasticities, low consumption levels (as seen earlier) and increasing share of consumers (noted previously) indicate that consumer demand for poultry may increase as incomes rise.

Table 2.10 shows own- and cross-price elasticities for different food groups including various sources of animal-proteins. As expected and consistent with the demand theory, own-price elasticities are negative for all food groups and different sources of animal proteins. In the North, all sources of animal proteins have own-price elasticity of less than 1 except for poultry meat. This indicates that a 1% increase in prices reduces the quantity demanded by less than 1% for all items except for poultry meat. For poultry meat, the own-price elasticity is negative and high at -1.26, showing that increase in prices disproportionately decreases the quantity demanded. However, egg elasticity is negative and lower than poultry meat (-0.82). This suggests that poultry producers in the region must focus on eggs and ensure its steady supply while trying to lower prices for poultry meat. Further, the lowest own-price elasticity among different sources of animal proteins is seen for beef (-0.71). This suggests that consumers in the North are least responsive to price changes in beef which again (coupled with observations earlier) support our finding that beef is the most important source of animal protein in the Northern diets.

In the South, own-price elasticities for all sources of animal proteins including poultry meat are less than one and quite low. This shows that south Nigerians are very less sensitive to prices of animal proteins as compared to the North. In fact the lowest price elasticity is for poultry eggs (-0.39). Together with growing demand and expansion of egg consumption, low price elasticity suggests that eggs are becoming an important part of diets in the South. This is a fantastic opportunity for poultry producers in the South for establishing fast-moving supply chains for both eggs and poultry meat.

Further, cross-price elasticities also reveal some interesting insights. On average, cross price elasticities across different animal source protein categories is generally low, particularly in the south. However, there are some important distinctions across regions. In the North where beef is an important animal protein, we find that increase in beef prices leads to a slight decline in the consumption of seafood (-0.19) and milk (-0.11), indicating that beef has no substitutes. In fact people reduce consumption of other items to be able to purchase more beef. This is not so surprising given the relatively low own-price elasticity of beef. Northern consumers responsiveness to changes in price of seafood is higher than that for beef and increase in seafood prices slightly increases consumption of eggs (0.07), and small ruminants (0.16) making them weak substitutes for seafood. We also find that eggs and meat are also weak substitutes for milk as indicated by cross-price elasticities of 0.26 and 0.19 respectively. However, comparing cross price elasticities across products we see that a relatively important substitute for seafood, milk and poultry meat in the north are pulses (an important plant protein source) with cross price elasticities of 0.26, 0.31 and 0.58 respectively.

In the South where seafood dominates as the animal protein source, we find no strong animal-protein substitutes for seafood. Beef and poultry meat are rather weak substitutes for seafood with cross-price elasticities of 0.00 and 0.06 respectively. Similar to the north, we find relatively stronger consumption responses to change in prices of animal proteins for pulses where the cross-price elasticity is 0.25 and 0.13 for milk and small ruminants respectively).

2.7. Conclusion and policy implications

Our analysis reveals that animal proteins are extremely important for Nigerian diets and while animal protein consumption has expanded in both the poorer North and more affluent South, there are important differences in the demand depending on regions (North vs South), areas (urban vs rural), and incomes. We summarize our findings below.

First, seafood is the most popular source of animal protein in Nigeria in both North and South across urban and rural areas and all income groups. In the South, almost all households consume at least some form animal proteins irrespective of income group and areas (urban or rural). This is further corroborated by expenditure elasticities which suggest that seafood is a necessity in the South while still a luxury in the North. Further, our cross-price elasticities also show that there is no strong animal-protein substitute to seafood in the South. Our results thus highlight that given the widespread importance of seafood in the South and its potential to feed the poor in the North, building robust production and supply chains are critical for improving food security in Nigeria via increased consumption of animal source proteins.

Second, beef is the second most important in terms of share of consumers in both North and South. Actually, in the North, while beef is a close second in terms of consumer share and per capita quantity, it ranks first in terms of budget share on animal proteins. Our income elasticities suggest that beef is a luxury across regions and income groups. Even though the income elasticity for beef is higher in the South than in the North, beef has lower own-price elasticity in the North than in the South. Additionally, cross-price elasticities show that beef has no substitutes in the North while in the South poultry meat, seafood, and eggs may weakly substitute for beef. Yet, in the North, the share of beef consumers and per capita quantity has declined over the decade without any increase in real prices (see Table 11) and is thus a matter of worry.

Third, based on our research, milk consumption levels in Nigeria are alarmingly low. However, a steady increase in the share of households consuming milk over the past decade, particularly in the Southern regions, appears to be due to the penetration of imported packaged milk such as chocolate drinks. High income elasticities for milk indicate that as incomes increase, the demand for milk will rapidly expand. Thus, attention needs to be paid to the dairy value chain so a sustainable milk supply chain is established to meet the growing demand for milk in Nigeria.

Fourth, the poultry industry has been experiencing significant growth in terms of both consumers and budget shares, with high income elasticities indicating that increasing incomes may result in greater demand for poultry meat and eggs in both regions. Notably, in the North, consumers exhibit a high sensitivity to the price of poultry meat. Thus, decreasing prices could drive up demand for poultry meat. Additionally, our research suggests that the rural areas dominate poultry meat consumption in the North. This is not so surprising because poultry production is prevalent in the rural areas of the North and lack of necessary infrastructure, such as supply chains and cold-storage facilities, make it difficult to transport perishable poultry products to urban areas. Overall, these findings underscore the potential for poultry (meat and eggs) to address malnutrition issues in Nigeria. However, it is critical to establish efficient supply chains that can connect production and consumption areas in a timely manner. Also, poultry being less resource-intensive and having shorter production cycles may be key to catering to the increased animal-protein demand in a sustainable manner.

Thus, our results emphasize that decline in consumption levels for important items, particularly in the North, given that real mean prices have not increased suggest that the issue possibly lies with production and supply chains. This is highly detrimental to incomes of producers which further exacerbates food insecurity challenges in the poorer North. Thus, demand-driven value chains of animal-proteins plays a crucial role in reducing malnutrition and catering to increasing demand in Nigeria.

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APPENDIX

Tables

Table 2.1: Mean real prices (in Naira)

	2010-2011			2012-2013			2015-2016			2018-2019		
Food groups	North	South	All	North	South	All	North	South	All	North	South	All
Cereals	122	180	153	117	221	174	123	196	164	97	169	133
Tubers	94	114	107	81	117	105	64	100	88	60	74	68
Pulses	155	143	148	165	262	221	139	170	157	220	347	286
Oils	288	302	296	249	262	256	240	322	287	256	416	338
Vegetables	222	303	267	124	152	140	177	179	178	158	146	152
Fruits	141	137	138	132	197	182	111	194	171	43	59	53
Beef	651	794	732	626	642	635	557	583	573	505	527	519
Seafood	527	585	567	657	499	547	554	541	545	347	457	423
Milk*	335	1334	878	270	1134	835	269	997	645	455	984	813
Poultry meat	571	676	631	790	680	723	587	558	566	458	668	567
Eggs	646	617	623	326	445	419	335	279	290	236	265	256
Small ruminants**	612	934	761	614	677	638	475	483	478	465	471	467
Other foods	301	465	388	167	264	222	212	272	244	206	286	246
Number of households	2494	2493	4987	2400	2310	4710	2312	2268	4580	2510	2465	4975

*Milk includes fresh milk and chocolate drinks
**Small ruminants include mutton, goat, pork, wild game meat, and other meats

Table 2.2: Share of households by areas (urban vs rural) and over time in North and South

	2010-2011			2012-2013			2015-2016			2018-2019		
						NORTH						
Food groups	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All
Animal proteins	95	87	89	99	90	92	98	89	91	93	87	89
Beef	75	57	61	73	52	56	72	49	54	68	43	48
Seafood	78	59	64	74	61	64	76	61	64	69	53	57
Milk*	35	31	32	39	35	36	38	34	35	47	29	33
Poultry meat	16	19	18	13	12	12	11	11	11	16	22	21
Eggs	27	7	12	20	10	12	31	12	16	36	19	22
Small ruminants**	25	27	26	30	34	33	25	38	34	22	22	22
Cereals	99	99	99	100	100	100	99	100	100	99	100	100
Tubers	78	65	68	85	77	79	83	75	77	87	81	82
Pulses	90	83	85	93	86	87	95	93	94	98	96	96
Oils	97	97	97	99	99	99	91	98	96	100	99	99
Vegetables	98	98	98	99	98	99	99	99	99	100	100	100
Fruits	50	27	32	48	30	34	58	48	50	78	59	63
Other foods	96	92	93	99	98	98	100	98	99	100	100	100
Number of households (N)	528	1966	2494	486	1914	2400	486	1826	2312	532	1978	2510
						SOUTH						
Food groups	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All
Animal proteins	99	99	99	99	100	99	99	100	100	99	99	99
Beef	68	56	62	70	62	66	70	62	67	73	63	67
Seafood	95	96	96	95	98	96	98	98	98	96	97	97
Milk*	36	26	31	53	47	51	36	29	33	65	61	63
Poultry meat	23	10	17	19	9	14	24	11	18	28	17	21
Eggs	41	21	32	43	19	32	56	35	46	56	45	49
Small ruminants**	17	19	18	16	18	17	17	21	19	7	16	12
Cereals	98	96	97	99	99	99	100	100	100	99	99	99
Tubers	95	88	92	99	100	100	99	100	99	99	100	99
Pulses	90	92	91	90	88	89	94	96	95	96	98	97
Oils	94	92	93	99	100	99	99	100	99	99	99	99
Vegetables	98	99	99	99	100	99	99	100	100	98	99	99
Fruits	61	55	58	74	80	77	88	91	89	86	80	83

Table 2.2 (cont'd)

Other foods	90	81	86	96	99	98	93	98	95	100	100	100
Number of households	1085	1408	2493	984	1326	2310	980	1288	2268	1056	1409	2465

For descriptives we included all households who consumed a particular item in the week prior to the survey in either of and both post planting and post-harvest. This increases the consumption values for different food items significantly compared to just using the share who consumed in either period separately. This might be because of seasonal accessibility and affordability constraints of a household. Thus, measuring yearly consumption allows us to get a better sense of desirability of products.

* Milk includes fresh milk and chocolate drinks

**Small ruminants include mutton, goat, pork, wild game meat, and other meats

Table 2.3: Share of households by per capita income (proxied by expenditure*)**

	2010-2011			2012-2013			2015-2016			2018-2019		
	NORTH											
Food groups	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
Animal proteins	75	94	97	83	95	99	88	98	99	84	94	96
Beef	37	67	80	40	59	75	46	71	71	38	56	78
Seafood	49	65	77	54	66	74	58	76	85	52	64	62
Milk*	23	31	44	32	33	47	33	37	44	25	43	45
Poultry meat	10	18	29	4	13	24	7	17	30	16	27	30
Eggs	2	9	28	8	11	21	9	25	56	10	35	51
Small ruminants**	20	27	33	26	37	34	35	35	30	19	27	27
Cereals	99	100	99	100	100	100	100	100	100	100	100	98
Tubers	57	70	78	70	80	89	72	85	94	76	90	89
Pulses	74	89	89	81	89	93	93	95	95	96	98	95
Oils	94	99	96	98	99	99	96	96	91	99	100	99
Vegetables	97	99	98	98	99	99	99	100	98	99	100	98
Fruits	14	34	52	21	33	57	41	67	80	54	73	85
Other foods	88	94	96	97	99	100	98	100	100	100	100	100
Number of households	724	1151	619	725	1189	486	1550	642	120	1425	836	249
	SOUTH											
Food groups	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
Animal proteins	97	99	100	99	100	99	100	100	99	99	99	98
Beef	33	61	74	32	62	77	50	74	79	46	69	74
Seafood	94	95	97	96	98	95	99	98	98	96	98	96
Milk*	5	24	47	19	47	60	19	35	51	35	62	74
Poultry meat	4	7	29	3	8	22	6	18	39	8	15	35
Eggs	9	21	49	6	23	44	27	54	65	26	44	66
Small ruminants**	12	16	21	9	16	19	16	20	22	10	12	14
Cereals	91	97	99	96	99	100	100	100	99	100	99	99
Tubers	76	93	96	98	100	99	99	100	99	100	100	99
Pulses	81	92	93	72	89	93	94	95	95	98	97	96
Oils	85	92	96	98	100	99	100	100	98	100	99	98
Vegetables	98	99	99	99	100	99	100	100	99	100	99	98
Fruits	33	51	72	65	78	79	83	92	96	72	81	89
Other foods	64	85	95	95	98	98	94	95	97	100	100	100
Number of households	484	980	1029	348	911	1051	885	956	427	412	1232	821

Table 2.3 (cont'd)

*Milk includes fresh milk and packaged milk
**Small ruminants include mutton, goat, pork, wild game meat, and other meats
***Terciles are created based on average per capita daily total expenditure of a household in both seasons (pre-harvest and post harvest : Tercile 1 (T1) : less than or equal to \$1.9, Tercile 2 (T2) : between \$1.9 and \$4, Tercile 3 (T3) : greater than \$4.

Table 2.4: Annual per capita consumption of animal proteins over time and regions (kg)

	2010-2011			2012-2013			2015-2016			2018-2019		
						NORTH						
Food groups	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All
Animal proteins	29.6	20.0	22.3	35.4	14.5	19.1	18.4	11.7	13.3	18.5	12.5	13.8
Beef	10.4	6.9	7.7	7.5	4.3	5.0	5.8	2.9	3.6	5.8	3.1	3.7
Seafood	12.7	7.7	8.9	7.2	5.5	5.9	8.1	5.3	6.0	7.9	5.7	6.1
Milk*	3.8	5.1	4.8	3.1	4.6	4.3	3.3	3.9	3.8	1.7	2.7	2.5
Poultry meat	2.2	2.4	2.4	1.6	1.4	1.5	1.1	0.7	0.8	1.8	1.8	1.8
Eggs	2.1	0.4	0.8	16.2	0.6	4.1	1.5	0.4	0.6	1.6	0.6	0.8
Small ruminants**	2.1	2.7	2.5	2.9	2.6	2.7	1.9	2.4	2.3	1.5	1.4	1.4
Cereals	184.6	229.9	219.1	159.0	188.2	181.8	138.6	165.9	159.5	118.2	146.7	140.8
Tubers	79.3	78.1	78.4	80.2	73.5	75.0	100.1	103.7	102.9	64.8	76.8	74.3
Pulses	31.3	30.0	30.3	31.3	40.7	38.6	17.4	19.8	19.3	15.5	16.9	16.6
Oils	24.1	19.2	20.4	18.2	15.7	16.3	13.7	12.2	12.6	12.5	11.1	11.4
Vegetables	54.3	44.7	47.0	60.7	42.8	46.7	30.7	21.1	23.3	34.9	26.3	28.1
Fruits	11.8	5.6	7.1	8.5	4.4	5.3	22.9	11.2	13.9	38.5	22.5	25.8
Other foods	56.8	25.2	32.7	49.7	21.1	27.4	39.2	14.2	20.0	130.6	33.6	53.4
Number of households	528	1966	2494	486	1914	2400	486	1826	2312	532	1978	2510
						SOUTH						
Food groups	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All
Animal proteins	35.1	35.2	35.1	26.1	23.4	24.9	28.0	24.2	26.3	31.3	32.9	32.2
Beef	7.8	6.0	7.0	7.0	5.7	6.4	7.4	5.5	6.5	7.9	6.6	7.1
Seafood	20.7	24.8	22.6	14.4	14.5	14.4	15.0	15.0	15.0	17.3	21.7	19.9

Table 2.4 (cont'd)

Milk*	1.2	4.1	2.6	0.8	1.0	0.9	0.5	0.5	0.5	0.8	1.0	0.9
Poultry meat	3.0	1.4	2.3	2.2	0.9	1.6	2.5	1.0	1.8	3.2	1.7	2.3
Eggs	2.1	0.9	1.5	1.4	0.4	1.0	2.1	0.8	1.5	2.4	1.6	1.9
Small ruminants**	1.4	2.2	1.8	1.1	2.0	1.5	1.1	1.8	1.4	0.5	1.4	1.0
Cereals	72.2	61.0	67.1	45.5	37.1	41.6	47.5	41.2	44.7	49.7	50.6	50.2
Tubers	113.2	106.8	110.2	106.4	139.1	121.7	112.0	175.1	140.7	120.0	204.8	169.3
Pulses	30.4	32.2	31.2	14.7	13.7	14.2	16.2	12.2	14.4	16.5	18.7	17.8
Oils	26.5	25.2	25.9	12.2	11.2	11.7	11.8	11.3	11.6	12.1	12.0	12.1
Vegetables	34.5	30.5	32.6	32.2	31.4	31.8	26.8	22.8	25.0	42.4	41.2	41.7
Fruits	14.6	13.0	13.8	16.8	16.5	16.7	32.0	30.1	31.1	42.5	38.7	40.3
Other foods	91.6	35.0	65.5	92.1	26.0	61.3	29.3	19.7	24.9	143.0	77.0	104.6
Number of households	1085	1408	2493	984	1326	2310	980	1288	2268	1056	1409	2465

*Milk includes fresh and packaged milk
**Small ruminants include mutton, goat, pork, wild game meat, and other meats

Table 2.5: Annual per capita consumption of animal proteins over income terciles (proxied by expenditure*) (kg)**

	2010-2011			2012-2013			2015-2016			2018-2019		
	NORTH											
Food groups	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
Animal proteins	9.5	20.5	41.0	6.7	15.8	47.9	8.0	20.0	42.7	6.8	18.9	37.2
Beef	2.5	7.6	14.1	2.1	4.9	10.1	2.1	5.6	10.7	1.6	4.8	12.4
Seafood	4.4	8.1	15.7	2.8	5.8	11.2	3.5	9.5	17.9	3.3	8.5	14.4
Milk*	3.8	4.7	6.3	4.0	4.5	4.2	3.5	4.2	4.5	2.4	2.9	1.7
Poultry meat	0.9	2.1	4.5	0.2	1.4	3.7	0.4	1.1	4.1	0.8	2.5	4.4
Eggs	0.1	0.5	2.3	0.4	1.0	18.2	0.2	0.9	4.7	0.2	1.1	3.1
Small ruminants**	1.5	2.2	4.5	1.2	2.8	4.8	1.8	3.0	5.3	0.9	2.0	3.0
Cereals	168.4	230.2	259.6	157.5	190.3	198.5	149.6	183.8	152.7	129.5	157.5	147.2
Tubers	36.9	73.6	137.2	31.0	79.3	134.1	72.4	149.2	233.0	52.0	99.0	118.0
Pulses	17.0	32.2	42.8	26.0	41.0	52.5	17.0	22.7	28.6	13.4	20.2	22.3
Oils	12.6	20.4	29.9	9.5	14.8	31.0	10.7	15.3	21.1	8.4	14.3	19.0
Vegetables	31.6	46.5	66.6	28.2	48.3	72.2	18.0	30.4	51.7	18.7	35.0	59.7
Fruits	1.2	5.8	16.4	1.7	3.8	15.0	6.8	22.0	58.5	14.4	32.5	69.5
Other foods	11.8	22.6	76.7	8.9	21.7	72.2	9.6	30.4	94.4	19.9	65.2	213.7
Number of households	724	1151	619	725	1189	486	1550	642	120	1425	836	249
	SOUTH											
Food groups	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
Animal proteins	14.4	26.5	49.3	9.2	17.4	33.8	15.0	27.1	44.2	11.3	26.6	48.4
Beef	1.9	5.2	10.2	0.9	3.8	9.5	3.3	6.9	11.5	1.7	5.8	11.1
Seafood	11.5	18.6	29.6	7.7	11.6	17.9	10.2	15.7	22.1	8.4	17.4	27.9
Milk*	2.1	1.7	3.5	0.2	0.6	1.2	0.2	0.4	1.0	0.6	0.7	1.4
Poultry meat	0.3	0.7	4.2	0.1	0.5	2.7	0.3	1.5	5.2	0.4	1.2	4.6
Eggs	0.2	0.8	2.6	0.1	0.4	1.6	0.5	1.6	3.0	0.4	1.3	3.4

Table 2.5 (cont'd)

Small ruminants**	0.5	1.2	2.7	0.4	1.0	2.2	0.8	1.5	2.6	0.5	0.9	1.4
Cereals	41.0	53.4	87.2	19.5	34.0	52.0	31.6	47.7	61.0	28.8	46.5	63.9
Tubers	43.0	101.8	139.8	87.6	116.7	132.8	113.3	152.8	163.0	131.0	170.9	182.2
Pulses	19.7	28.1	37.7	5.4	12.1	17.6	10.2	14.9	20.6	10.8	16.4	22.5
Oils	11.5	21.1	34.8	6.6	9.7	14.4	8.1	12.1	16.4	6.7	11.1	15.6
Vegetables	17.8	28.3	41.2	16.6	26.2	39.2	16.9	27.0	34.9	21.5	38.6	54.0
Fruits	3.6	9.8	20.7	7.5	10.8	23.0	14.4	31.4	59.7	15.7	30.5	63.8
Other foods	9.4	40.4	105.4	6.4	26.9	98.5	7.4	24.1	57.2	25.1	60.0	199.0
Number of households	484	980	1029	348	911	1051	885	956	427	412	1232	821

*Milk includes fresh milk and chocolate drinks
**Small ruminants include mutton, goat, pork, wild game meat, and other meats
**Terciles are created based on average per capita daily total expenditure of a household in both seasons (pre-harvest and post harvest : Tercile 1 (T1) : less than or equal to $1.9, Tercile 2 (T2) : between $1.9 and $4, Tercile 3 (T3) : greater than $4.

Table 2.6: Share of different FV items in the FV expenditure budget over regions and over time

	2010-2011			2012-2013			2015-2016			2018-2019		
	NORTH											
Food groups	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All
Animal proteins	20.9	17.9	18.6	22.1	18.5	19.3	19.9	14.9	16.1	17.3	14.1	14.8
Beef	45.3	38.0	39.9	38.2	29.7	31.9	40.2	29.2	32.4	41.2	31.8	34.1
Seafood	31.2	30.7	30.9	34.3	35.1	34.9	33.2	33.2	33.2	26.5	28.9	28.3
Milk*	4.9	7.2	6.6	5.0	7.6	6.9	5.8	7.6	7.1	6.0	8.3	7.7
Poultry meat	6.3	11.0	9.7	6.5	9.2	8.5	5.6	5.9	5.8	10.1	15.0	13.8
Eggs	4.5	1.5	2.3	3.1	1.2	1.7	4.0	1.7	2.4	4.5	2.3	2.8
Small ruminants**	7.8	11.7	10.7	13.0	17.1	16.0	11.2	22.4	19.1	11.6	13.8	13.3
Number of households (N)	528	1966	2494	486	1914	2400	486	1826	2312	532	1978	2510
	SOUTH											
	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All
Animal proteins	29.5	31.9	30.6	25.8	25.8	25.8	28.1	26.1	27.2	25.5	24.2	24.7
Beef	28.7	21.6	25.3	31.3	23.4	27.6	29.8	24.3	27.4	32.0	24.8	27.9
Seafood	49.8	63.2	56.2	47.4	57.9	52.3	50.6	60.9	55.1	43.8	55.0	50.1
Milk*	4.5	3.5	4.0	5.5	6.3	5.9	3.4	2.7	3.1	6.3	5.3	5.8
Poultry meat	7.5	3.2	5.4	7.3	3.9	5.7	8.7	3.9	6.6	11.8	7.4	9.3
Eggs	4.8	2.4	3.6	4.5	1.1	2.9	4.4	2.1	3.4	4.3	2.9	3.5
Small ruminants**	4.8	6.1	5.4	4.0	7.5	5.6	3.1	6.0	4.4	1.8	4.7	3.4

Table 2.5 (cont'd)

Number of households	1085	1408	2493	984	1326	2310	980	1288	2268	1056	1409	2465

*Milk includes fresh milk and chocolate drinks
**Small ruminants include mutton, goat, pork, wild game meat, and other meats

Table 2.7: Share of different FV items in the FV expenditure budget across income groups* and over time**

	2010-2011			2012-2013			2015-2016			2018-2019		
	NORTH											
	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
Animal proteins	13.5	19.2	23.8	14.5	20.1	24.8	13.8	19.6	26.0	11.8	17.7	22.4
Beef	32.6	42.5	41.2	30.3	31.8	33.6	30.6	35.9	29.7	29.6	35.4	44.6
Seafood	36.2	30.7	27.5	38.1	34.2	33.5	31.9	35.0	34.4	30.9	28.1	20.7
Milk*	8.4	6.0	6.1	10.8	6.1	4.9	8.6	5.2	4.4	9.9	6.3	4.9
Poultry meat	9.7	9.2	10.5	3.9	8.9	12.1	4.8	6.1	11.7	13.2	14.0	15.2
Eggs	0.7	1.7	4.2	1.2	1.6	2.5	1.5	2.7	6.9	1.4	3.7	4.8
Small ruminants**	12.4	10.0	10.5	15.7	17.4	13.4	22.6	15.1	12.8	15.0	12.5	9.9
Number of households	724	1151	619	725	1189	486	1550	642	120	1425	836	249
	SOUTH											
	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
Animal proteins	28.2	29.5	32.3	20.5	24.0	28.3	23.4	28.3	31.3	18.6	23.7	28.7
Beef	17.1	26.7	26.6	13.1	25.3	31.4	23.2	29.2	29.5	19.6	29.2	28.4
Seafood	74.6	59.9	48.0	77.8	57.7	44.9	65.7	53.1	45.2	64.7	51.8	44.4
Milk*	1.0	3.1	5.6	2.8	5.8	6.4	1.9	3.2	4.4	4.6	5.5	6.3
Poultry meat	1.8	2.2	8.9	1.5	3.1	8.0	2.4	6.2	12.9	4.8	6.6	13.6
Eggs	1.7	2.8	4.7	0.6	1.9	3.9	2.2	3.9	4.0	2.2	3.2	4.2
Small ruminants**	3.8	5.2	6.1	4.3	6.1	5.5	4.7	4.4	3.9	4.1	3.6	3.0
Number of households	484	980	1029	348	911	1051	885	956	427	412	1232	821

*Milk includes fresh milk and chocolate drinks
**Small ruminants include mutton, goat, pork, wild game meat, and other meats
***Terciles are created based on average per capita daily total expenditure of a household in both seasons (pre-harvest and post harvest : Tercile 1: less than or equal to $1.9, Tercile 2: between $1.9 and $4, Tercile 3: greater than $4.

Table 2.8: Median expenditure elasticities by region

	North			South		
	All	Urban	Rural	All	Urban	Rural
Cereals	0.79	0.75	0.80	0.73	0.73	0.73
Tubers	1.37	1.29	1.41	0.86	0.82	0.89
Pulses	1.14	1.07	1.17	0.74	0.71	0.77
Oils	0.77	0.78	0.77	0.67	0.68	0.65
Vegetables	0.75	0.73	0.75	0.56	0.53	0.58
Fruits	2.48	2.09	2.62	1.21	1.20	1.21
Beef	2.01	1.62	2.15	1.44	1.32	1.60
Seafood	1.38	1.20	1.47	0.74	0.74	0.73
Milk*	1.77	1.73	1.78	2.19	2.04	2.36
Poultry meat	3.79	3.53	3.87	2.85	2.60	3.18
Eggs	2.77	2.31	2.94	1.96	1.79	2.23
Small ruminants**	1.87	1.59	1.98	2.02	1.99	2.06
Other foods	1.08	1.06	1.08	1.31	1.28	1.35

*Milk includes fresh milk and chocolate drinks

**Small ruminants include mutton, goat, pork, wild game meat, and other meats

Table 2.9: Median expenditure elasticities by income terciles (proxied by total expenditure)**

	North			South		
	T1	T2	T3	T1	T2	T3
Cereals	0.82	0.78	0.69	0.76	0.74	0.70
Tubers	1.52	1.28	1.31	0.97	0.87	0.75
Pulses	1.29	1.08	1.01	0.83	0.75	0.66
Oils	0.76	0.79	0.78	0.63	0.64	0.72
Vegetables	0.79	0.72	0.72	0.58	0.56	0.54
Fruits	2.90	2.35	1.93	1.28	1.22	1.16
Beef	2.67	1.75	1.28	2.19	1.50	1.11
Seafood	1.68	1.28	1.11	0.67	0.71	0.80
Milk*	1.85	1.74	1.60	3.01	2.29	1.74
Poultry meat	4.49	3.50	2.72	4.21	2.97	2.40
Eggs	3.13	2.66	2.25	2.76	2.03	1.62
Small ruminants**	2.44	1.65	1.42	2.34	2.08	1.77
Other foods	1.08	1.09	1.06	1.51	1.35	1.17

*Milk includes fresh milk and chocolate drinks

**Small ruminants include mutton, goat, pork, wild game meat, and other meats

Table 2.10: Median own- and cross-price elasticities

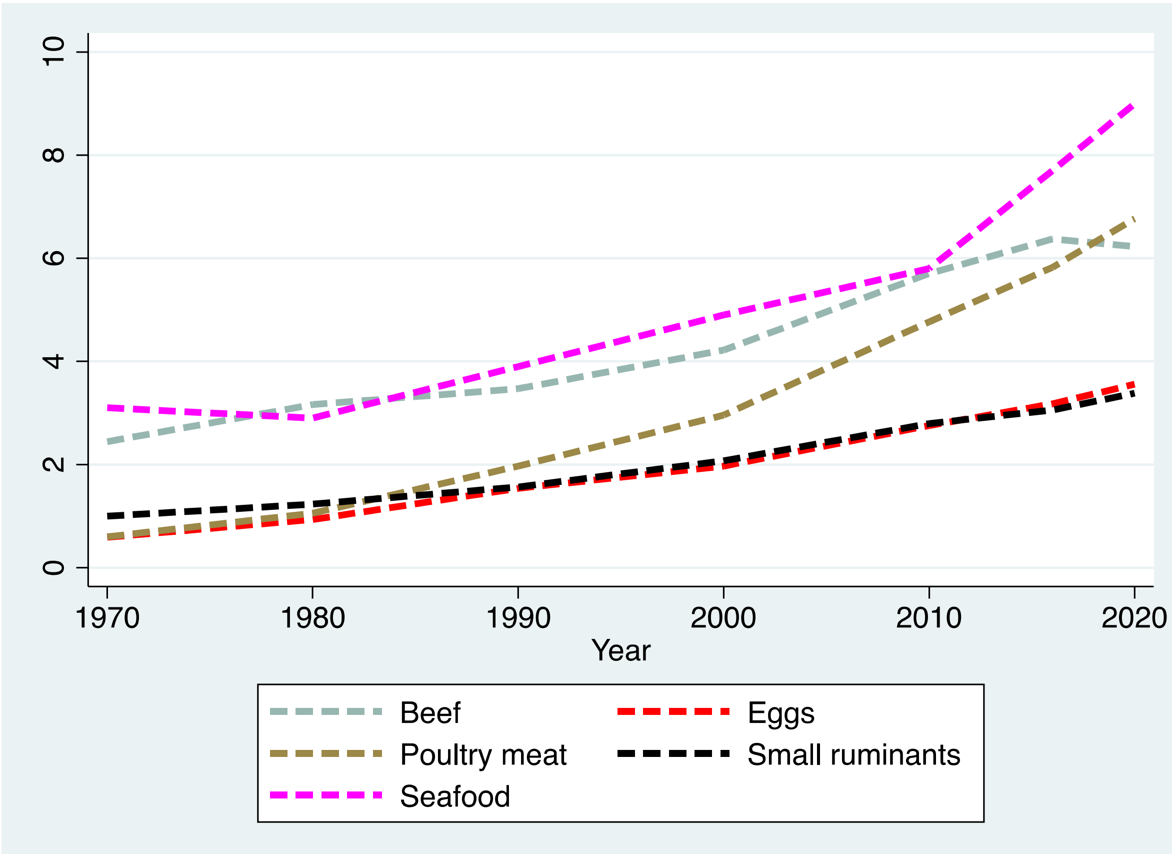
NORTH													
	Cereals	Tubers	Pulses	Oils	Vegetables	Fruits	Beef	Seafood	Milk*	Poultry meat	Eggs	Small ruminants**	Other foods
Cereals	-0.79	0.32	-0.06	0.16	-0.18	0.25	-0.24	0.11	-0.21	-0.13	-0.30	0.20	-0.04
Tubers	-0.03	-0.93	0.00	0.00	-0.02	0.00	0.00	0.07	-0.06	-0.07	-0.15	0.09	-0.03
Pulses	0.02	-0.31	-0.74	-0.05	0.10	0.18	0.04	0.26	0.31	0.09	0.58	-0.01	0.10
Oils	-0.05	-0.09	-0.15	-0.69	-0.06	-0.18	0.37	-0.13	-0.52	0.44	-0.10	-0.15	0.12
Vegetables	-0.05	0.06	-0.05	0.00	-0.73	0.03	0.10	-0.02	0.17	-0.25	0.12	-0.07	-0.04
Fruits	-0.02	-0.10	-0.07	-0.08	0.01	-1.05	-0.02	0.00	0.07	0.02	0.08	0.16	-0.05
Beef	0.01	-0.17	-0.27	0.11	0.01	0.05	-0.71	0.04	-0.22	-0.18	-0.37	-0.37	0.26
Seafood	0.00	0.10	0.02	0.00	-0.07	-0.39	-0.19	-0.95	-0.15	-0.22	-0.22	0.06	-0.10
Milk*	0.01	-0.05	0.02	-0.02	-0.03	-0.13	-0.11	-0.04	-0.83	-0.03	-0.39	0.04	-0.03
Poultry meat	-0.02	0.09	-0.07	-0.03	0.01	-0.39	0.01	0.00	0.26	-1.26	-0.44	-0.34	-0.22
Eggs	-0.01	-0.01	0.04	0.00	-0.01	0.02	0.01	0.07	0.19	-0.19	-0.82	-0.03	-0.02
Small ruminants**	0.01	0.01	0.10	-0.03	-0.10	-0.14	-0.12	0.16	-0.12	-0.30	0.36	-0.86	-0.05
Other foods	-0.02	0.02	0.13	-0.11	-0.22	-0.34	-0.36	0.02	-0.15	-0.55	0.04	0.34	-1.17
SOUTH													
	Cereals	Tubers	Pulses	Oils	Vegetables	Fruits	Beef	Seafood	Milk	Poultry meat	Eggs	Small ruminants	Other foods
Cereals	-0.86	0.44	-0.21	0.34	0.09	0.49	-0.09	-0.22	0.19	0.97	-0.16	-0.10	0.04
Tubers	-0.03	-0.69	-0.01	0.11	0.01	-0.12	0.06	0.07	-0.11	-0.33	0.01	-0.29	-0.01
Pulses	-0.09	0.20	-0.80	0.09	-0.08	-0.19	0.02	0.02	0.25	-1.27	-0.01	0.13	0.23
Oils	0.12	0.11	0.05	-0.46	-0.25	0.10	-0.05	-0.08	0.42	-0.09	0.11	-0.31	0.08
Vegetables	-0.09	0.23	-0.14	0.00	-0.79	-0.12	-0.01	0.12	0.09	0.08	-0.52	-0.11	-0.05
Fruits	0.03	0.00	0.03	0.02	0.05	-0.81	-0.09	-0.01	0.11	-0.29	0.16	0.68	0.05
Beef	0.06	-0.06	-0.01	-0.09	0.12	0.02	-0.92	0.00	-0.22	0.18	0.13	-0.23	-0.04
Seafood	-0.08	0.13	-0.05	-0.18	-0.09	-0.02	0.06	-0.80	-0.04	0.44	-0.03	-0.68	-0.11
Milk	0.05	0.10	0.03	0.02	0.04	-0.05	0.02	-0.01	-0.73	-0.10	-0.21	-0.08	0.08

Table 2.10 (cont'd)

Poultry meat	0.03	0.11	-0.04	0.07	0.03	0.06	0.09	0.06	0.05	-0.88	-0.08	-0.17	-0.01
Poultry eggs	0.00	-0.08	0.03	0.06	0.01	0.14	0.02	-0.03	0.08	0.06	-0.38	0.25	-0.02
Small ruminants	-0.01	-0.07	-0.01	-0.04	-0.03	0.01	0.03	-0.01	0.10	-0.14	0.06	-0.79	0.05
Other foods	-0.09	0.14	-0.09	-0.34	-0.09	-0.34	-0.16	-0.14	0.20	0.12	-0.39	-0.55	-0.95

*Milk includes fresh milk and chocolate drinks
**Small ruminants include mutton, goat, pork, wild game meat, and other meats

Figure 2.1. Africa's meat production (million tons)



CHAPTER 3: DO SMALLER CHICKEN FARMS USE MORE ANTIBIOTICS? EVIDENCE ON ANTIBIOTICS DIFFUSION NIGERIA

Parkhi, C. M., Liverpool-Tasie, L. S. O., & Reardon, T. (2023). Do smaller chicken farms use more antibiotics? Evidence of antibiotic diffusion from Nigeria. *Agribusiness*, *39*(1), 242-262.

3.1. Introduction

Farmers have added antibiotics to water and feed for livestock, including chicken, since the early 1900's. Antibiotics were first introduced for therapeutic purposes (ex post) in animal agriculture in Britain in 1938 (Kirchhelle, 2018). In 1948, antibiotics were introduced into poultry feed, and in 1949, it was discovered that low (sub-therapeutic) doses of antibiotics in feed prevented disease and promoted animal weight gain. Thus, by the 1950s antibiotics were seen as useful to farmers as an ex post therapeutic treatment and an ex-ante prophylactic treatment that reduced mortality, increased feed efficiency, and reduced labor costs for animal health monitoring and care (Sneeringer et al., 2015).

Over the next 70 years, starting in the US and Western Europe, antibiotics use in animal production rapidly spread to the developing areas of Asia and Latin America and Eastern Europe. That diffusion in developing regions was driven by three sets of factors that were part of the broader transformation of diets and agriculture. First, animal production has followed the growth in meat demand caused mainly by rising incomes over the past three decades. Poultry had the most dramatic gains of any meat (OECD-FAO, 2021). This was predictable from Bennett's Law (Bennett, 1941) associated with the disproportionate increase in demand for non-staples such as animal proteins, and fruits and vegetables with rises in income. Second, there has been an increase over time in farmers' demand for variable inputs to intensify animal production including feed and antibiotics to reduce the risk of disease that accompanies higher density of animals on a farm, and to reduce labor requirements for monitoring and caring for animal health. Antibiotics also magnified the efficiency of feed use by growth promotion (Grace, 2015; Robinson et al., 2011). Third, increased production and exports of animal antibiotics, in particular by Chinese firms, drove down the price and drove up the ease of access to animal antibiotics for farmers in developing regions (Kirchhelle, 2018).

A two-stage trend was observed in each developing region as antibiotics use spread. There was an initial focus on the spread of antibiotics use over farms for therapeutic reasons as they intensified and became more commercialized (albeit with average farm sizes much smaller than in the US). Then there was a focus on antibiotics use especially for prophylaxis, as that became widespread (such as in Thailand, see Van Boeckel et al. 2012 and Wongsuvan et al. 2018).

With the intensive use of antibiotics, and especially the wide diffusion of prophylactic use of antibiotics on farms in the US and Western Europe, concerns emerged about the development of antimicrobial resistant (AMR) strains of bacteria in animals which are then sometimes transmitted to humans through food ingestion by consumers and animal handling by farm workers (Sneeringer et al., 2015; Grace, 2015).[8] The AMR concern spread to other regions as antibiotics diffusion proceeded. For example, the Asian literature has recently begun to address antibiotics resistance in animal agriculture (Alam et al., 2019; Imam et al., 2020; Van Boeckel et al., 2012; Wongsuvan et al., 2018; Xu et al., 2020).

Sub-Saharan Africa (SSA) has up to recently been the outlier in antibiotic diffusion in animal agriculture, mainly because animal production was largely “extensive” and traditional until recently. For example, poultry were mainly free-range near homesteads, and little commercial feed and medicine was used. There is emerging evidence however that with the onset of the various drivers of the rise of animal production and consumption discussed above but now relevant in SSA, there has been an emergence of poultry intensification in general and the use of antibiotics in particular. But as SSA is in the early stages of poultry intensification, antibiotics diffusion has received limited attention so far in the literature. The few studies of that emergence of poultry intensification combined with use of antibiotics (such as Chaiban et al., 2020) have been focused on medium and large farms, and not yet examined the use of antibiotics by small farmers, which are in the great majority.

Our paper aims at reducing that gap in the literature with a case study of Nigeria. There have been a few studies of poultry farmers’ use of antibiotics in Nigeria, but they have tended to be of specific sites/communities, using small samples, and mainly descriptive (e.g., Ojo et al., 2016, Oluwasile et al., 2014, and Alo and Ojo, 2007). Filling that gap in knowledge will better prepare SSA to address issues of antibiotics resistance and avian diseases (and zoonosis in general) as they replicate and expand in the next decades with intensification in poultry farming. Indeed, there is already “early” concern emerging of Africa’s facing antibiotics resistance and contamination in poultry farming. A recent study in urban Cameroon found emerging antibiotics resistance (Kamini et al., 2016).

We address three questions hitherto not tested in the African context, in the context of Nigerian poultry farming: (1) How does antibiotics use per bird vary over different farm sizes?

[8] When same type of antibiotics is used over and over again, the bacteria develops an ability to defeat the drug rather than get killed by it. This thus reduces effectiveness of antibiotics and renders them useless. If antibiotics are to be used to extended periods, exposure to same type of antibiotics could be avoided by using different types of drugs.

(2) How does heterogeneity in intra-country regional economic development affect antibiotics use per bird? (3) To what extent are antibiotics used only for therapy versus for prophylaxis or growth promotion?

The answers to these research questions are important for several reasons. First, there has been little research on how the extent of farming intensification (via antibiotics such as use per bird) correlates with inter-farm-scale and inter-region heterogeneity, and thus whether it is primarily the larger farms in the more favorable regions that are intensifying in general and adopting antibiotics or are small farms in general and less favorable regions also adopting. There has been a bias at least in the African debate that mainly the large "company farms" are undertaking these changes but small farmers are not. If small farmers (and even poorer regions) are also adopting antibiotics in SSA, it is crucial for government extension systems to first add more emphasis on poultry production per se, and second to institute programs of training on correct dosing and use of antibiotics to be more effective and induce the least AMR.

Second, if the Nigerian case shows what one finds in the US and Asia, widespread antibiotics use for prophylaxis and high use per bird being associated with AMR, then this will be a cause for concern for agriculture and health. This concern will be heightened if we also find that small farms share in these patterns and thus risk experiencing or being a cause of AMR.

Nigeria is an interesting case because it is the most populous African country and has great variation in development over regions. This allows for the robustness of antibiotics diffusion patterns to be tested in a manner that is comparable with many African countries. We study two states in Nigeria (Oyo and Kaduna) as the contrast between the more developed South and the poorer North. Our study is based on a survey of 1386 chicken farms across different farm sizes that allows us to respond to the questions noted above.

The paper proceeds as follows. Section 1.2 presents the theoretical framework underlying our empirical analysis, Section 1.3 presents our data. Section 1.4 and 1.5 present the empirical model and study results respectively. Section 1.6 concludes and provides some policy implications.

3.2. Theoretical framework

Our theoretical framework incorporates the multiple motives of antibiotics use - as a prophylactic, for therapeutic use, and for growth enhancement - in the chicken farmer's production function. The model used here builds on the damage control function developed by

Lichtenberg and Zilberman (1986) for pesticide use.[9] Damage control is measured as the share of the "destructive capacity of the damaging agent eliminated by the application of a level of control agent" (Lichtenberg and Zilberman, 1986).

Let $G(D(S),\ x)$ be the damage control function where x is the quantity of antibiotics administered per bird (damage control agent), D the probability of disease transmission in the presence of a sick bird, and S the flock size (Waterfield and Zilberman, 2012; Lichtenberg and Zilberman, 1986). We assume that for a given farm area, D is a function of S, and is increasing in S. Larger flocks, because of density, are typically more susceptible to infectious diseases than smaller flocks in the same enclosure space (Refregier-Petton et al., 2001, Kaneene et al., 2002, and Akey, 2003). As there is typically a correlation between the density of the flock (birds in the enclosure) and the overall size of the farm in Nigeria, we use farm size in terms of flock size as a proxy for density.[10] Even though the probability of occurrence of disease in an individual bird might be small, the transmission of disease and the probability of infection in a herd confined in a particular space is greater for larger flocks than that for smaller flocks controlling for the enclosure space (Thomas et al., 2005).

The damage control function (G) is decreasing in D but increasing in x. It takes values between 0 and 1. $G = 1$ indicates that the damage has been completely controlled, while $G = 0$ indicates maximum destruction. If there are no sick chickens, $G\ (0, x)$ captures the prophylactic use of antibiotics. Damage control or abatement is defined as the share of destructive capacity eliminated by a level of the damage control agent used. Thus, as the number of diseased birds increases, marginal abatement due to a unit of damage control agent increases, that is, $G_x\ (D(S), x)$ is increasing in D. Therefore, $G_x\ (D, x) > G_x\ (0, x)$ where $D > 0$.

Hence, given the damage control function, production for a farmer in terms of expected quantity of bird meat produced per cycle is given by

$$Q = S * \omega[\boldsymbol{z}, x, G(D(S), x), \boldsymbol{H}] - - - - - (1)$$

where ω denotes the weight function of a bird;[11] $\boldsymbol{z}$ is the vector of inputs other than antibiotics used in chicken production such as feed, water, electricity etc.; x is the level of antibiotics per

[9] See recent studies such as Barrows et al. (2014) and Möhring et al. (2020) using a similar framework for pesticide use.

[10] We do not have precise estimates of the enclosure or yard sizes of the chicken farms.

[11] The weight function here is agnostic about functional forms and breed as we focus on the direction of the impact of the elements, particularly flock size.

bird; G is the extent of damage control during the cycle; and S is the flock size. Output per cycle is increasing in flock size (S) and other inputs ($\boldsymbol{z}$). $\boldsymbol{H}$ is the vector of household and farm characteristics such as age, gender, and farm location that may affect production. When no antibiotics are used, $\omega[\boldsymbol{z}, \boldsymbol{H}]$ is the weight of a bird at the maximum level of destruction and no growth promoters.

Therefore, the profit maximization of the farmer may be set up as follows:

$$Max_{x,\boldsymbol{z}}\, S * \{p * \omega[\boldsymbol{z}, x, G(D(S), x), \boldsymbol{H}] - C[\boldsymbol{z}, x, p_x, \boldsymbol{p_z}]\} - - - (2)$$

where p denotes the per kg price of bird meat; and C denotes the cost function for raising a bird. For simplicity, we assume that there are no economies of scale and hence the cost function is independent of flock size. We relax this assumption below to show that our results hold even in the presence of economies of scale.

Recall that one of our research questions is the relationship between demand for antibiotics (x) and flock size (S). To separately assess this relationship for therapeutic and non-therapeutic uses of antibiotics, we consider two cases. First, we assume that antibiotics serve as growth promoters alone (i.e., $G = 0$). Solving for profit maximization gives the input demand function for antibiotics:

$$x^* = x(p, p_{\mathrm{x}}, \boldsymbol{p_z}, \boldsymbol{H}) - - - - - (3)$$

The input demand function in equation (3) suggests that antibiotics, when used as growth promoters, are independent of flock size.

Second, we now introduce the therapeutic use of antibiotics captured by the damage control function G. In this case, the input demand function is given by:

$$x^* = x(p, p_{\mathrm{x}}, \boldsymbol{p_z}, S, \boldsymbol{H}) - - - - - (4)$$

Equations (3) and (4) together imply that the demand for antibiotics changes with flock size due to their use as damage control agents. This is because the damage control function (G) is a function of the probability of disease transmission (D) which in turn depends on the flock size (S). Recall that the probability of disease transmission increases with flock size. Therefore, the damage abatement captured by (G) decreases with increasing flock size and the marginal benefit (or damage abatement) provided by a unit of antibiotics increases with flock size. Thus, we infer that larger farms use more antibiotics per bird to protect their flock against disease transmission.

Specifically, three hypotheses emerge from the model above. First, as antibiotics serve the dual purpose of growth promotion and damage control, we hypothesize that the demand for antibiotics is higher the larger the flock. Moreover, a larger flock may be positively correlated with commercialization. Therefore, in the absence of any government or private regulations, we expect more use of antibiotics among larger farms compared to smaller farms. Another mechanism through which smaller farms might be less likely to use antibiotics is if small farms tend to consume a higher share of their production and thus are more concerned about negative effects of antibiotics use on their health.

Recall that our basic model assumes the absence of economies of scale. However, relaxing this assumption to include economies of scale in administering antibiotics could also explain why large farms use more antibiotics to achieve lower marginal costs. Therefore, antibiotic use could be positively associated with scale for both damage control and growth enhancement.

Second, from equations (3) and (4) we expect that household characteristics (such as farm assets, farmer education and gender) will affect the use of antibiotics. While the model does not predict the direction of the relationship, it is expected that agro-ecological and regional development ($\boldsymbol{H}$) may influence antibiotic availability, commercial payoff to technology change, and chicken disease incidence.

Third, we hypothesize that antibiotic use increases with disease incidence as sub-therapeutic doses are generally administered for prophylaxis and growth promotion. This hypothesis is based in earlier findings in the literature (Kirchhelle, 2018; Sneeringer et al., 2015) as well as the predictions of our model. Given that the damage control function G measures the destructive capacity eliminated using antibiotics, as the probability of disease transmission (given the presence of sick birds) increases, the marginal benefit from a unit of antibiotics increases. Thus, demand for antibiotics increases with the increase in disease probability which is higher in the presence of sick birds. Therefore, when no sick birds are present, antibiotics are used for prophylaxis in quantities smaller than that used for curative purposes.

3.3. Data and descriptive analysis

Our data are from a survey of chicken farms in two Nigerian states (Oyo and Kaduna). These states have both experienced rapid growth in chicken farming in the past two decades. However, Kaduna is in the poorer, hotter, and drier North while Oyo is the more developed and more humid South. Our sampling approach in these states was as follows.

First, in each state, we sampled local government areas (LGAs) with the most chicken production in terms of the volume of chicken production. Note that an LGA is the third administrative level of government in Nigeria, equivalent to a US county. As chicken farms tend to cluster near chicken consumption areas, the selected LGAs tend to be close to large urban areas. Our sample in the south was selected near Ibadan, a city with a population of 3 million and the capital of Oyo State. In the greater Ibadan area, there are 11 LGAs; of these we selected the two top LGAs. These production zones also send a lot of chicken to Nigeria's commercial capital city Lagos which is about 130 km to the southwest of Ibadan. Our sample in the north was selected near Kaduna, a city with a population of 1.3 million and the capital of Kaduna State. In the greater Kaduna area, there are four LGAs which correspond to the major chicken producing areas that feed Kaduna. We selected all four.

In each selected LGA, we stratified its wards into low, medium, and high production areas in terms of volume of chicken production. In each of the medium and high wards, we listed all chicken farmers. For the household farmers we randomly selected 600 farmers in each state. For the non-household farms (farms keeping chicken away from their household), we included all farms that were identified in the selected LGAs (84 in Oyo and 82 in Kaduna) in our sample. Our final sample includes 1366 farmers. Because there were non-responses to some relevant questions, this study includes information on 1093 chicken farmers across 9 LGAs in the two study states: 615 farmers in Oyo state and 478 farmers in Kaduna state.[12] Given that some farmers owned more than one farm, our analysis consists of 1386 farms: 832 in Oyo and 554 in Kaduna.

Due to missing values of some explanatory variables such as age, gender, well/borehole, and distance to the nearest highway, the number of observations in our regressions is less than 1000. We conducted robustness checks (with about 1315 observations for quantity of antibiotics per bird and 1312 observations for expenditure per bird) after dropping these variables and our main results are maintained (Appendix B).

The survey collected detailed information on farming and marketing in the previous production cycle. This included detailed information about poultry medicines administered, their prices and quantities, and the method of administration. We also collected socio-economic information about the farmers. During the training and survey pretest, the main kinds and forms

[12] To reduce concerns about systematic differences between those farms for which we do not have information and those included in our study, we compare other socioeconomic factors across our sample and the total sample and do not find evidence of any systematic difference between those dropped due to nonresponse and our final sample.

of medicines used by poultry farmers in the study regions were identified. We observed (during training and data collection) that farmers are for the most part able to remember basic information such as expenditures on medicines, quantities used per batch applied, and prices of the medicines. Most farmers had a standard batch size they restocked. Our results are robust to the use of expenditures in value terms (which might be considered easier to recall compared to quantities) and quantities.

Table 3.1 presents the demographic characteristics of the study sample. The typical farmer is a 45-year-old male with about 8 years of experience in poultry farming. While 19% belong to a farmers' association, this varies across the two study states. Membership in a poultry association is significantly higher in Oyo (28%) compared to Kaduna (7%). Almost half (48%) of our sample stated that poultry farming is their primary source of income. To capture heterogeneity in scale of operation, we divided the study farms into flock size terciles. Small farms have a flock size of fewer than 100 birds, while medium and large farms have flock sizes of 100-1000 and greater than 1000 birds respectively.[13]

Table 3.2 presents data on antibiotic use among farmers by scale in the two study states. In both states, antibiotics use (share of farms using antibiotics) is higher among medium and large farms compared to small farms. On the other hand, conditional on adoption, the quantity of antibiotics used (per bird) declines with flock size. Further, we consistently find that antibiotics use is higher in Kaduna than Oyo. In Kaduna, 76% of farms use antibiotics (compared to 54% in Oyo) and the average quantity used per bird and expenditure per bird (among those using antibiotics) is 1.64 grams and 8 Naira ($1equals 428.74 Naira) per bird respectively (compared to 1.06 grams and 9 Naira in Oyo). Across farm sizes, we find that antibiotics adoption among both small and large farms is higher in Kaduna (at 48% and 96% respectively) compared to Oyo (at 15% and 74% respectively). Finally, in terms of quantity per bird among those using antibiotics, small and medium farms in Kaduna use higher quantities than those in Oyo. However, large farms in Kaduna use smaller quantity per bird (0.35 grams) than those in Oyo (0.82 grams).

There is considerable difference in antibiotics expenditure per bird among farms of different sizes in the two study states. While small farms in Kaduna tend to spend more (per bird) on

[13] This farm size classification is specific to our data set for Nigeria and in other economies; the farms considered to be large here might still be considered small or medium. However, the farm size used here is based on the terciles of the data, conversations in the field, information from the PAN, and the natural breaks in the classification. For example, the minimum flock size variable for medium-scale farms, based on the terciles, is 100 birds.

antibiotics compared to small farms in Oyo, medium and large farms in Oyo spend higher (per bird) compared to medium and large farms in Kaduna. We suspect that price of antibiotics may vary with quality as well as method of administration. Higher quality antibiotics and antibiotics when administered by a veterinary professional might cost more per unit compared to those administered by farmers themselves.

Table 3.3 shows the quantity of antibiotics used per bird (among those who used antibiotics) across flock sizes and by disease incidence. As expected, farms with a disease incident use higher quantities per bird compared to those using antibiotics for non-therapeutic purposes. On average, the quantity per bird of antibiotics used by small farms is about 5 times higher than large farms. Further, we see that the quantity of antibiotics used per bird decreases with size for both therapeutic and non-therapeutic purposes. This indicates that small farms use higher quantity of antibiotics per bird irrespective of purpose. We suspect that small farms administer antibiotics without veterinary advice and hence tend to use higher quantities.

Taken together these use rates among small and medium farms with a disease incident (and the fact that less than 10% of farms faced a disease incident in the last production cycle shown in Table 3.1) supports the idea that significant amounts of antibiotics are largely being used for non-therapeutic purposes. Assuming that a bird produces about 2.5kg of meat, farms that adopted antibiotics use about 540 mg per kg (1.35 grams per bird). Compared with the global average of 148 mg per kg (Van Boeckel et al., 2015), quantities used in Nigerian poultry farming are high as also seen in other developing countries such as Nepal and Vietnam (Koirala et al., 2021; Carrique-Mas et al., 2014).

3.4. Regression model and estimation method

Recall that our theoretical model suggests that the use of antibiotics increases with flock size because the probability of disease is higher in larger flocks. It also suggests that antibiotic use will increase with the level of regional economic development and marketed surplus rates of farmers. Moreover, the model predicts that farmers use more antibiotics for therapeutic purposes than that for non-therapeutic purposes.

When empirically testing these predictions of the theoretical model, a corner solution approach is appropriate because, in the Nigerian context, some farmers have chosen to not use antibiotics although these items have been accessible in the rural markets for some years, and we assume that most farmers are aware of antibiotics (and their use in poultry farming). The many observations of zero use of antibiotics in our data can thus be interpreted as arising from economic decisions of farmers who could access these items if they wanted to or could afford it or both (Ricker-Gilbert, 2011). While a Tobit model could be used to estimate the decision of antibiotic use in this case, it is restrictive in the sense that it assumes the underlying process of adoption and its extent to be the same (Burke, 2009).[14] Thus, we adopt the double-hurdle model which allows for different mechanisms to govern the adoption decision (y= 0 vs y > 0) and the "extent of adoption decision" (amount of y if y > 0). More specifically, the double-hurdle model allows for variables such as commercialization (marketed surplus), flock size, and education to have different effects on the decision to use antibiotics versus the quantity used.

The first hurdle, analogous to Cragg's (1971) model, uses a probit regression to estimate the probability of antibiotics adoption by poultry farmers. The decision for each farmer i can be expressed as:

$$Y_i = [\beta_1 X_{1i} + \varepsilon_i] \; \varepsilon_i \sim N(0,1) -----(5)$$

where Y_i is a binary variable that equals 1 if the farmer uses a non-zero quantity of antibiotics and 0 otherwise.

The second hurdle estimates the extent of adoption of antibiotics conditional on adoption using a truncated normal regression:

$$Q_i = [\beta_2 X_{2i} + v_i | Y_i = 1] \;\; v_i \sim N(0, \sigma^2) -----(6)$$

where Q_i denotes the quantity of antibiotics used.

X_{1i} and X_{2i} are vectors of explanatory variables that affect the two stages and are assumed to be uncorrelated with ε_i and v_i respectively and β_1 and β_2 are corresponding parameter vectors to be estimated. Thus, the resulting likelihood function for the two hurdles may be represented as

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[14] We conducted a likelihood ratio test to compare the Tobit model and Cragg's double-hurdle model (DHM). The null hypothesis we test is that the Tobit model is a better fit as compared to the DHM. The number of regressors is 18. Therefore, the number of parameters for Tobit is 20 and DHM has an additional 19 parameters. For the DHM on quantity of antibiotics per bird, the loglikelihood for tobit (LLT) is -1404.2575 and that for DHM (LLC) is -1189.237. Therefore, the loglikelihood ratio given by $-2(\text{LLT} - \text{LLC}) = 430.041 > \chi^2(19) = 36.19$ at 1% level of significance. Thus, we reject the null hypothesis that theTobit model has a better fit than the DHM.

For the DHM on expenditure of antibiotics per bird, the loglikelihood for Tobit (LLT) is -1522.753 and that for DHM (LLC) is -1343.6571. Therefore, the loglikelihood ratio given by $-2(\text{LLT} - \text{LLC}) = 358.1918 >$ $\chi^2(19)$ 36.19 at 1% level of significance. Thus, we reject the null hypothesis that the Tobit has a better fit than the DHM.

$$f(Y,Q|X_{1,}X_2) = \{1-\Phi(\beta_1{}'X_1)\}^{Y=0}\left[\frac{\Phi(\beta_1{}'X_1)(2\pi)^{-\frac{1}{2}}\sigma^{-1}\exp\left\{\frac{-(Q_i - X_2\beta_2)^2}{2\sigma^2}\right\}}{\Phi\left(\frac{\beta_2{}'X_2}{\sigma}\right)}\right]^{Y=1} \quad --(7)$$

where Φ denotes the standard normal cumulative density function.

The original model by Cragg (1971) assumes that the error terms in the two hurdles are independent and normally distributed. Several studies that relaxed the assumption of independent error terms have found that the results are similar irrespective of the assumption (e.g., Bellemare and Barrett, 2006; Burke et al., 2015). We maintain Cragg's original assumption. Therefore, the empirical specification of the first stage regression is as follows:

$$Antibiotic\ use_i = \beta_1 + Flock\ size_i * \beta_2 + Disease_i * \beta_3 + H_i * \beta_2 + \varepsilon_i --- (8)$$

where the dependent variable is the binary variable =1 if a farmer i used antibiotics and zero otherwise. ε_i denotes the normally distributed error term with mean 0. $Flock\ size_i$ is a vector of binary variables for terciles based on flock size (*medium*, a binary variable that equals 1 if the flock size is in the medium tercile and 0 otherwise; *small*, a binary variable that equals 1 if the flock size is in the small tercile and 0 otherwise). H_i is a vector of household characteristics and agro-ecological factors. It includes the following variables:

$Age\ of\ household\ head\ (in\ years)$;

$Male\ household\ head\ (\ binary\ variable\ that\ equals\ 1\ if\ gender\ is\ male)$;

$Poultry\ as\ the\ primary\ income$ (a binary variable);

Well/borehole ownership (binary variable);

$Distance\ to\ the\ nearest\ highway$ (in km) of the farm;

$Social\ network$ (the number of people the farmer discusses farming related issues outside of family with);

$Membership\ in\ a\ poultry\ association$ (a binary variable);

$Record\ keeping$ (a binary variable);

$Poultry\ farming\ training$ (a binary variable);

$Multiple\ family\ members\ involved\ in\ poultry$ (a binary variable);

$Experience$ (number of years involved in chicken farming)

$Kaduna\ state$ (a binary variable, with the intercept being Oyo state);

$Other\ medicines$ (a binary variable whether the farmer gives non-antibiotic medicines to the birds, such as vitamins, hormones, and vaccines;

$Hybrid\ breed$ (whether the birds in the farm are hybrid breeds or local breeds)

In the second step, we measure the extent of adoption in two ways: quantity used per bird (measured in grams) and expenditure per bird (measured in the Nigerian currency, Naira). Following Reynolds and Shonkwiler (1991), we apply the Inverse Hyperbolic Sine Transformation (IHS) to the quantity of antibiotics and antibiotics expenditures. The IHS transformation is known to handle extreme values well (Yen and Jones, 1997). The equation used is:

$$quantity_i = \gamma_1 + Flock\ size_i * \gamma_2 + Disease_i * \beta_3 + H_i * \gamma_2 + v_i \quad ----(9)$$

The independent variables are as described in step 1 and v_i denotes the normally distributed error term with mean 0.

As an alternative measure of adoption intensity, we also estimate equations (8) and (9) but with expenditure on antibiotics (inverse hyperbolic sine transformed) used per bird as the dependent variable rather than the quantity of antibiotics used per bird. We estimate the Cragg's double hurdle model using the craggit command in Stata and calculate unconditional and conditional Average Partial Effects following Burke (2009).[15]

3.5. Regression results

Table 3.4 presents the results from the double hurdle models on antibiotic use using the entire sample. Panel A of Table 3.4 shows the marginal effects for the double hurdle model where the extent of adoption is measured as the quantity of antibiotics used per bird. Panel B of Table 3.4 shows the marginal effects for the double hurdle model where the extent of adoption is measured as expenditure on antibiotics used per bird. They also present the unconditional effects of various factors on antibiotic used. Following Bellemare and Wichman (2020), inverse hyperbolic sine transformation was treated as natural logarithm. Therefore, marginal effects seen in the table are semi-elasticities. Six key findings emerge.

First, the probability of adoption of antibiotics is higher among medium and large farms compared to small farms. As seen from column (1) of Table 3.4, being a medium scale farm is associated with 9.2 percentage points higher probability of using antibiotics compared to a small farm, all else equal. On the contrary, among farmers that use antibiotics, the extent of adoption in terms of quantity per bird is lower for medium and large farms compared to small farms. Column

[15] See Burke (2009) for further details on the construction of average partial effects from the Cragg double-hurdle model as applied here.

(2) of Table 3.4 shows that the quantity of antibiotics used by medium and large farms are 79.6% and 132% lower than the amount used by small farms respectively.

Columns (4) and (5) of Table 3.4 reveal similar results when the extent of adoption is measured as expenditure per bird rather than quantity. While being a medium farm is associated with significantly higher probabilities of using antibiotics, medium and large farms are associated with lower expenditures per bird, all else being equal.

Although we find that the use of any antibiotics is positively associated with farm size (as predicted by the theoretical model), the results on the amount used are contrary to our first hypothesis that the quantity used increases with flock size. Greater quantities used by smaller farms might indicate that these farms are less aware of the technical details associated with antibiotics use (compared to larger farms). Thus, smaller farms perhaps overuse antibiotics and could have used less with the same yield outcomes.

Second, contrary to our expectations, we find that being in the region of lower economic development is positively associated with antibiotic use. Column (1) of Table 3.4 shows that being a farmer in Kaduna (in the relatively poorer northern region of Nigeria) is associated with a 13.7 percentage point higher probability of using antibiotics compared to Oyo (in the relatively richer south). Further, being a farmer in the north is associated with a 59.3% higher quantity of antibiotics compared to the south (column 2). On one hand, these results might reflect differences in agro-ecological conditions. The south has more stable temperatures and humidity; the north has more variation with both. Daily temperature ranges in the dry season in the north can be quite large. Rainfall is heavier in the south with about 70 inches (1,800 mm) in the southwest compared to parts of the north that receive no more than 20 inches (500 mm) a year (Britannica, 2021). This higher variation and more extreme climate might increase poultry susceptibility to disease and encourage higher preventative use of antibiotics in the north. On the other hand, these results might reflect lower awareness of technical details among farmers in the north such that farmers there perhaps use higher antibiotics than needed to achieve similar yield outcomes.

However, column (5) shows that being a farmer in the north is associated with 84% lower antibiotic expenditures than farmers in the south, all else being equal. We find that the average price of antibiotics in Kaduna is significantly lower (1,055 Naira/kg) compared to Oyo (1,948

Naira/kg) which might reflect that the type and quality of antibiotic use might vary significantly across regions.

Third, a farm with disease incidence is associated with only a 4 .5 percentage points higher probability of antibiotics use (see Columns (1) and (5)) compared to those without any disease. However, conditional on adoption, disease is positively correlated with amount of antibiotics used (in quantity terms and value of expenditure terms) (Columns (2) and (5)). This is consistent with our hypothesis that farmers use higher amounts of antibiotics for therapeutic purposes as compared to non-therapeutic uses. However, our results on adoption reflect that antibiotic use is widespread for non-therapeutic purposes in Nigeria.

Fourth, our results indicate that the use of antibiotics is correlated with the adoption of other modern production techniques. Investing in other medicines and the use of hybrid birds are both associated with higher probability (40 and 16 percentage points respectively) of using antibiotics.

Fifth, farms that administered antibiotics on their own (without any veterinary help) are more likely to adopt antibiotics as seen in columns (1) and (4) of Table 3.4. The quantity used is also positively correlated with administering antibiotics without any veterinary assistance (higher by 86%). However, no significant correlation is observed between administering medicines without veterinary help and antibiotics expenditure per bird.

Sixth, a wider social network (number of other farmers a farmer discusses poultry farming with) has nearly no effect on antibiotics adoption. However, conditional on use, the quantity used is positively associated with farmers network by 3.6%. The surprise here is the small effect of the farmers' network on adoption or quantities. This may be because farmers hear what they might think is sufficient information from medicine vendors and extension agents. The latter interpretation seems to be corroborated by the positive effect on adoption of membership in a poultry association. Antibiotics dealers often have "field days" with farmers associations to show them new products and explain when to use their medicines.[16]

One of our objectives is to discern the extent to which farmers are using antibiotics for therapeutic or non-therapeutic purposes. To do that we exclude from our sample all farms that experienced a disease in the production cycle for which data was collected. We assume that the

[16] This issue of input dealer promotion to farmer associations is based on anecdotal evidence from fieldwork and a rapid reconnaissance (field visit to actors along the poultry value chain in Nigeria that was conducted before fieldwork).

remaining farmers used antibiotics for non-therapeutic reasons. Table 3.5 presents the results from the double hurdle models on the determinants of antibiotic use for non-therapeutic purposes. Even in this reduced sample, with no experience of disease in the immediate past season, we find the same main results as discussed above in Table 3.4. Note that our data only show disease incidence in the same season for which we have data about antibiotic use; thus we cannot tell whether the farmers that use the medicine as prevention this year are not recalling a disease experience some years before and taking steps to avoid what to them may seem likely to be repeated. As noted in the introduction, it is common in livestock farming, whether by small or large farmers, in many countries for farmers to use antibiotics preventatively. They could also be influenced by other farmers' experiences and/or exposure to information from input dealers or radio programs or extension.

While we make no judgements about whether the quantity of antibiotics used for non-therapeutic purposes is excessive, our descriptive statistics confirm that use rates in Nigeria tend to be significantly higher (about 3.5 times) than the global average. Our results inform policy and program prescriptions to optimize antibiotics use in chicken production. Excessive use of antibiotics not only increases costs but also leads to antimicrobial resistance among animals and humans rendering antibiotics ineffective for medicinal use.

3.6. Conclusion

In our analysis of chicken farms in Nigeria, we observe that antibiotics use is already widespread among chicken farms of all sizes and across both the richer south and less affluent north. We also find that disease incidence during the season is not economically significant for the adoption of antibiotics. On the contrary, antibiotics adoption is consistently high among all farmers, irrespective of their disease experience. This confirms the use of antibiotics for prophylactic and perhaps growth enhancement purposes in Nigeria.

We find that the probability of antibiotics use increases with flock size but the quantity used per bird is higher among smaller farmers. Our results suggest antibiotics use might be more efficient among larger farmers; that the smaller the farm the greater the indiscriminate use of antibiotics. These results reveal that the contribution of small farms in potentially creating a problem of antibiotics resistance in developing countries should not be overlooked.

We also found that information plays a role in adoption, but not information from social networks (these have only a tiny effect) but rather from membership in associations. The latter are favorite venues for chemical vendors to do field days for instruction and sale.

These findings indicate the importance of working with farmers associations alongside extension agents and private input dealers to increase awareness about appropriate antibiotics use. The study findings are also particularly important for countries with poor food regulation systems and a large share of smallholder non-commercialized farmers who are both producers and consumers of chicken. In the absence of regulations and regulation enforcement, smaller semi-commercialized farmers are more likely to care about the health effects of consuming the chickens they produce. Thus, efforts to promote more awareness are likely to be more effective with improved regulation on antibiotics use for poultry products.

While our data cannot distinguish between different types of antibiotics, further research exploring the types of antibiotics and their frequency of use is needed. Such information will further allow us to investigate if farms "switch up" antibiotics rather than using the same ones for extended periods. Using different types of antibiotics will help limit the spread of antimicrobial resistance as poultry intensification takes place and the need for antibiotics rises.

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APPENDIX A: TABLES

Table 3.1: Demographic characteristics of the study sample

Variables	All	Oyo	Kaduna
Age in years	45.36	48.92	40.91
Male farmer (1/0)	0.82	0.77	0.87
Poultry as a primary source of income (1/0)	0.48	0.45	0.52
Membership in a poultry association (1/0)	0.19	0.28	0.07
Experience in years	8.22	8.44	7.91
Owns a well/borehole (1/0)	0.86	0.89	0.81
Farmer keeps records of expenses (1/0)	0.53	0.53	0.53
Farmer received training in poultry related practices (1/0)	0.33	0.39	0.23
Social network (number of people the farmer discusses poultry farming with)	2.55	3.29	1.43
Another family member involved in poultry (1/0)	0.45	0.40	0.53
Observations*	1386	832	554

*Note: that the number of observations varies due to missing information.

Table 3.2: Descriptive statistics by flock size and state

Variables	Oyo				Kaduna			
	All	Small	Medium	Large	All	Small	Medium	Large
Share of farms using antibiotics (1/0)	0.54	0.15	0.82	0.74	0.76	0.48	0.84	0.96
Disease incidence (1/0)	0.08	0.11	0.08	0.06	0.05	0.06	0.05	0.03
Unconditional								
Quantity per bird (grams)	0.56	0.33	0.83	0.60	1.24	1.64	1.56	0.34
Expenditure per bird (Naira)	3.47	1.05	6.69	3.62	4.30	5.15	5.43	1.72
Conditional on antibiotic use								
Quantity per bird (grams)	1.06	2.32	1.02	0.82	1.64	3.43	1.86	0.35
Expenditure per bird (Naira)	9.43	10.64	11.64	7.23	7.85	17.67	8.25	1.81
Observations	832	311	223	298	554	176	222	156

Table 3.3: Quantity of antibiotics (grams per bird) conditional on antibiotics use*

Flock size	All farms	Farms with disease incidence	Farms with no disease incidence
Small	3.05	4.37	2.95
Medium	1.45	2.31	1.39
Large	0.62	1.09	0.59
All	1.35	2.16	1.29
Observations	841	55	818

*: among farms that used antibiotics.

Note: Of 1386 farms, 873 farms use antibiotics. However, due to missing values of quantities we have 841 observations here.

Table 3.4: Cragg's double hurdle model on antibiotic use for all purposes (among the entire sample)

	Panel A (Quantity per bird)			Panel B (Expenditure per bird)		
Variables	Antibiotics use (1/0) (1)	Quantity (Conditional) (2)	Quantity (Unconditional) (3)	Antibiotics use (1/0) (4)	Expenditure (Conditional) (5)	Expenditure (Unconditional) (6)
Flock size						
Medium farm (1/0)	0.092***	-0.796***	-0.350***	0.091***	-0.764***	-0.203
	(0.027)	(0.172)	(0.130)	(0.027)	(0.173)	(0.151)
Large farm (1/0)	0.038	-1.326***	-0.829***	0.030	-1.976***	-1.243***
	(0.030)	(0.193)	(0.145)	(0.031)	(0.203)	(0.162)
Level of development						
Kaduna (1/0)	0.137***	0.593***	0.698***	0.138***	-0.872***	-0.121
	(0.024)	(0.144)	(0.110)	(0.024)	(0.147)	(0.130)
Agroecological & Technology factors						
Disease incidence (1/0)	0.045*	0.639***	0.553***	0.047*	0.445**	0.480**
	(0.027)	(0.231)	(0.178)	(0.027)	(0.217)	(0.203)
Antibiotics Administered by farmer (1/0)	0.066***	0.861***	0.712***	0.063***	0.050	0.253**
	(0.020)	(0.135)	(0.096)	(0.019)	(0.160)	(0.124)
Other medicines (1/0)	0.394***	0.055	0.874***	0.387***	0.467**	1.637***
	(0.041)	(0.204)	(0.143)	(0.041)	(0.182)	(0.171)
Hybrid birds (1/0)	0.158***	-0.396	0.095	0.171***	-0.336	0.400*
	(0.045)	(0.261)	(0.182)	(0.046)	(0.255)	(0.217)
Household characteristics						
Information						
Social network	-0.005**	0.036*	0.014	-0.005**	-0.029	-0.037**
	(0.002)	(0.020)	(0.014)	(0.002)	(0.024)	(0.018)

Table 3.4 (cont'd)

Family member involved in poultry	-0.016	-0.210	-0.175	-0.018	-0.512***	-0.406***
	(0.017)	(0.163)	(0.114)	(0.017)	(0.143)	(0.112)
Poultry association member (1/0)	0.076***	0.016	0.172	0.078***	0.223	0.435***
	(0.026)	(0.173)	(0.139)	(0.026)	(0.159)	(0.148)
Received training (1/0)	-0.001	-0.216	-0.148	0.002	-0.389***	-0.254**
	(0.021)	(0.144)	(0.109)	(0.021)	(0.141)	(0.116)
Others						
Nearest highway	0.001	0.027***	0.020***	0.001	0.037***	0.029***
	(0.001)	(0.003)	(0.003)	(0.001)	(0.004)	(0.004)
Age	0.001	0.013**	0.011**	0.001	-0.015**	-0.006
	(0.001)	(0.007)	(0.005)	(0.001)	(0.006)	(0.005)
Male (1/0)	-0.006	0.118	0.068	0.002	-0.256	-0.166
	(0.020)	(0.164)	(0.116)	(0.021)	(0.159)	(0.124)
Poultry is primary income (1/0)	0.020	-0.132	-0.049	0.018	-0.132	-0.027
	(0.023)	(0.137)	(0.104)	(0.023)	(0.130)	(0.112)
Experience (1/0)	0.001	0.009	0.008	0.001	0.036***	0.027***
	(0.001)	(0.010)	(0.007)	(0.001)	(0.010)	(0.008)
Own a well/bore (1/0)	0.041	-0.497***	-0.239*	0.038	0.302*	0.323**
	(0.029)	(0.190)	(0.141)	(0.029)	(0.170)	(0.142)
Keeps records (1/0)	0.057***	0.191	0.248**	0.065***	0.070	0.272**
	(0.021)	(0.135)	(0.102)	(0.022)	(0.131)	(0.118)
Observations	974	974	974	971	971	971

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Note that although we have 1386 observations for antibiotic use, we have only 1354 observations for quantity of antibiotics used. Due to the missing data for age, gender, and distance to the nearest highway, the number of observations reduced to 974 for quantity and 971 for expenditure.

Table 3.5: Cragg's double hurdle model on antibiotic use for non-therapeutic purposes (observations with no disease incidence)

Variables	Panel A (Quantity per bird)			Panel B (Expenditure per bird)		
	Antibiotics use (1/0) (1)	Quantity (Conditional) (2)	Quantity (Unconditional) (3)	Antibiotics use (1/0) (4)	Quantity (Conditional) (5)	Quantity (Unconditional) (6)
Flock size						
Medium farm (1/0)	0.098***	-0.843***	-0.372***	0.095***	-0.827***	-0.240
	(0.028)	(0.174)	(0.129)	(0.027)	(0.170)	(0.154)
Large farm (1/0)	0.040	-1.300***	-0.809***	0.030	-2.013***	-1.273***
	(0.031)	(0.193)	(0.144)	(0.032)	(0.209)	(0.175)
Level of development						
Kaduna (1/0)	0.143***	0.611***	0.721***	0.144***	-0.799***	-0.067
	(0.026)	(0.143)	(0.112)	(0.026)	(0.150)	(0.134)
Agro ecological & Technology factors						
Antibiotics Administered by farmer (1/0)	0.066***	0.880***	0.720***	0.063***	0.117	0.293**
	(0.020)	(0.140)	(0.100)	(0.020)	(0.167)	(0.127)
Other medicines (1/0)	0.381***	0.055	0.834***	0.375***	0.600***	1.655***
	(0.041)	(0.211)	(0.140)	(0.040)	(0.169)	(0.169)
Hybrid birds (1/0)	0.171***	-0.461*	0.087	0.187***	-0.458	0.386*
	(0.049)	(0.280)	(0.191)	(0.049)	(0.280)	(0.233)
Household characteristics						
Information						
Social network	-0.005**	0.040*	0.017	-0.005**	-0.005	-0.021
	(0.002)	(0.021)	(0.015)	(0.002)	(0.023)	(0.017)
Family member	-0.018	-0.251	-0.206*	-0.020	-0.564***	-0.446***
	(0.017)	(0.166)	(0.115)	(0.018)	(0.153)	(0.119)

Table 3.5 (cont'd)

Poultry association member (1/0)	0.076***	-0.049	0.124	0.079***	0.266	0.465***
	(0.028)	(0.181)	(0.143)	(0.028)	(0.180)	(0.167)
Received training (1/0)	-0.003	-0.284*	-0.197*	-0.001	-0.420***	-0.287**
	(0.021)	(0.150)	(0.110)	(0.021)	(0.143)	(0.117)
Others						
Nearest highway	0.001	0.027***	0.021***	0.001	0.036***	0.029***
	(0.001)	(0.003)	(0.003)	(0.001)	(0.004)	(0.004)
Age	0.001	0.018***	0.014***	0.001	-0.013*	-0.004
	(0.001)	(0.007)	(0.005)	(0.001)	(0.006)	(0.005)
Male	-0.005	0.142	0.086	0.003	-0.327*	-0.212
	(0.022)	(0.168)	(0.122)	(0.023)	(0.168)	(0.144)
Poultry is primary income (1/0)	0.026	-0.182	-0.071	0.025	-0.156	-0.023
	(0.024)	(0.144)	(0.112)	(0.024)	(0.137)	(0.123)
Experience (1/0)	0.001	0.006	0.007	0.001	0.033***	0.026***
	(0.001)	(0.010)	(0.007)	(0.001)	(0.009)	(0.007)
Owns a well/bore (1/0)	0.049	-0.572***	-0.270*	0.046	0.310*	0.354**
	(0.032)	(0.201)	(0.145)	(0.031)	(0.180)	(0.152)
Keeps records (1/0)	0.047**	0.241*	0.261**	0.056**	0.087	0.247**
	(0.020)	(0.135)	(0.102)	(0.022)	(0.129)	(0.115)
Observations	916	916	916	913	913	913

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Although we have 1386 observations for antibiotic use and 1354 for expenditure per bird, missing values for age, gender, distance to the nearest highway reduces the number of observations here to 974 for quantity and 971 for expenditure. Further dropping farms that experienced disease reduces the number of observations to 916 and 913 for quantity and expenditure respectively.

APPENDIX B: SUPPLEMENTAL TABLES

Table 3.6: Cragg's double hurdle model on antibiotic use for all purposes (among the entire sample)

	Panel A (Quantity per bird)			Panel B (Expenditure per bird)		
Variables	Antibiotics use (1/0) (1)	Quantity (Conditional) (2)	Quantity (Unconditional) (3)	Antibiotics use (1/0) (4)	Quantity (Conditional) (5)	Quantity (Unconditional) (6)
Flock size						
Medium farm (1/0)	0.068***	-0.685***	-0.289***	0.067***	-0.718***	-0.219
	(0.024)	(0.158)	(0.110)	(0.024)	(0.171)	(0.138)
Large farm (1/0)	0.040	-1.310***	-0.748***	0.034	-1.895***	-1.082***
	(0.028)	(0.177)	(0.122)	(0.028)	(0.189)	(0.146)
Level of development						
Kaduna (1/0)	0.113***	0.481***	0.542***	0.113***	-0.827***	-0.135
	(0.019)	(0.129)	(0.089)	(0.019)	(0.126)	(0.104)
Agroecological & Technology factors						
Disease incidence (1/0)	0.053**	0.542***	0.473***	0.054**	0.354*	0.429**
	(0.023)	(0.196)	(0.141)	(0.023)	(0.208)	(0.172)
Antibiotics Administered by farmer (1/0)	0.082***	0.894***	0.718***	0.079***	0.300*	0.465***
	(0.020)	(0.118)	(0.083)	(0.020)	(0.154)	(0.118)
Other medicines (1/0)	0.449***	0.256	1.084***	0.446***	0.506***	1.875***
	(0.036)	(0.175)	(0.122)	(0.036)	(0.186)	(0.164)
Hybrid birds (1/0)	0.168***	-0.885***	-0.115	0.174***	-0.781***	0.220
	(0.041)	(0.287)	(0.172)	(0.041)	(0.264)	(0.212)
Household characteristics						
Information						
Social network	-0.006***	0.016	-0.002	-0.006***	-0.010	-0.028*
	(0.002)	(0.021)	(0.014)	(0.002)	(0.021)	(0.015)

Table 3.6 (cont'd)

Family member in poultry	-0.004	-0.035	-0.030	-0.005	-0.280**	-0.191**
	(0.016)	(0.135)	(0.090)	(0.016)	(0.123)	(0.095)
Poultry association member (1/0)	0.073***	0.306*	0.360***	0.076***	0.364**	0.514***
	(0.026)	(0.180)	(0.136)	(0.026)	(0.157)	(0.139)
Received training (1/0)	-0.003	-0.130	-0.087	-0.001	-0.208	-0.135
	(0.020)	(0.132)	(0.094)	(0.020)	(0.135)	(0.105)
Others						
Poultry is primary income (1/0)	0.030	-0.134	-0.024	0.029	0.010	0.106
	(0.020)	(0.129)	(0.090)	(0.019)	(0.127)	(0.101)
Experience (1/0)	0.001	0.005	0.005	0.001	0.013	0.012*
	(0.001)	(0.009)	(0.006)	(0.001)	(0.010)	(0.007)
Keeps records (1/0)	0.057***	0.086	0.173*	0.063***	-0.061	0.182*
	(0.020)	(0.132)	(0.092)	(0.021)	(0.131)	(0.110)
Observations	1315	1315	1315	1312	1312	1312

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 3.7: Cragg's double hurdle model on antibiotic use for non-therapeutic purposes (observations with no disease incidence)

Variables	Panel A (Quantity per bird) Antibiotics use (1/0) (1)	Quantity (Conditional) (2)	Quantity (Unconditional) (3)	Panel B (Expenditure per bird) Antibiotics use (1/0) (4)	Quantity (Conditional) (5)	Quantity (Unconditional) (6)
Flock size						
Medium farm (1/0)	0.073***	-0.716***	-0.302***	0.071***	-0.737***	-0.221
	(0.026)	(0.156)	(0.108)	(0.026)	(0.174)	(0.142)
Large farm (1/0)	0.043	-1.330***	-0.759***	0.036	-1.918***	-1.094***
	(0.031)	(0.177)	(0.124)	(0.031)	(0.201)	(0.161)
Level of development						
Kaduna (1/0)	0.115***	0.477***	0.539***	0.114***	-0.786***	-0.113
	(0.021)	(0.132)	(0.094)	(0.021)	(0.133)	(0.110)
Agroecological & Technology factors						
Antibiotics Administered by farmer (1/0)	0.082***	0.888***	0.713***	0.080***	0.279*	0.449***
	(0.020)	(0.120)	(0.086)	(0.020)	(0.157)	(0.116)
Other medicines (1/0)	0.451***	0.241	1.063***	0.448***	0.590***	1.904***
	(0.036)	(0.177)	(0.117)	(0.036)	(0.178)	(0.160)
Hybrid birds (1/0)	0.166***	-0.899***	-0.130	0.173***	-0.852***	0.172
	(0.043)	(0.301)	(0.182)	(0.044)	(0.293)	(0.229)
Household characteristics						
Information						
Social network	-0.007***	0.015	-0.004	-0.007***	-0.005	-0.026*
	(0.002)	(0.022)	(0.015)	(0.002)	(0.021)	(0.015)
Family member in poultry	-0.006	-0.106	-0.079	-0.007	-0.290**	-0.206**
	(0.017)	(0.144)	(0.096)	(0.017)	(0.128)	(0.100)

Table 3.7 (cont'd)

Poultry association member (1/0)	0.075**	0.289	0.352**	0.078***	0.380**	0.529***
	(0.029)	(0.187)	(0.143)	(0.029)	(0.172)	(0.154)
Received training (1/0)	-0.003	-0.125	-0.085	-0.002	-0.209	-0.137
	(0.020)	(0.143)	(0.098)	(0.020)	(0.135)	(0.108)
Others						
Poultry is primary income (1/0)	0.036*	-0.174	-0.037	0.035	-0.056	0.085
	(0.022)	(0.130)	(0.093)	(0.021)	(0.131)	(0.108)
Experience (1/0)	0.001	0.008	0.007	0.001	0.014	0.013**
	(0.001)	(0.009)	(0.006)	(0.001)	(0.009)	(0.007)
Keeps records (1/0)	0.049**	0.145	0.192**	0.055***	-0.041	0.163
	(0.020)	(0.130)	(0.092)	(0.021)	(0.128)	(0.108)
Observations	1223	1223	1223	1221	1221	1221

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1