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Food Security Crop Price Transmission and Formation in Nigeria

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FOOD SECURITY CROP PRICE TRANSMISSION AND FORMATION IN NIGERIA

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LIST OF ABBREVIATIONS

ADF	Augmented Dickey-Fuller test of series stationarity
ADP	Agricultural development projects
AfSIS	African Soil Information Service
AMIS-FAO	Agricultural Market Information System administered by the Food and Agricultural Organization of the United Nations
CBN	Central Bank of Nigeria
CILSS	Comite Permanent Inter-Etats de Lutte Contre la Secheresse Dans le Sahel (Permanent Interstate Committee for Drought Control in the Sahel)
CMG	Climate Modeling Grid
CPI	Consumer price index
CountrySTAT	Food and agriculture data network of the FAO
ECM	Error correction mechanism
EOSDIS	Earth Observing System Data and Information System
EPT	Estimated price transmission
FAO	Food and Agricultural Organization of the United Nations
FAOSTAT	Database of the Statistics Division of the Food and Agricultural Organization of the United Nations
FCT	Federal Capital Territory
FDAE	Federal Department of Agricultural Extension
FEWS-NET	Famine Early Warning System Network
FMARD	Federal Ministry of Agriculture and Rural Development
FMARD-FSRD	Federal Ministry of Agriculture and Rural Development Food and Strategic Reserve Department
FRED	Federal Reserve Economic Database
G-20	Group of Twenty

GIEWS	Global Information and Early Warning System
GON	Government of Nigeria
HDF-EOS	Hierarchical Data Format of the Earth Observation System
HEG	HDF-EOS to GeoTiff Conversion Tool
IEG	Independent Evaluation Group
IFPRI	International Food Policy Research Institute
IFS	International Financial Statistics database
IMF	International Monetary Fund
KNARDA	Kano State Agricultural and Rural Development Authority
LOP	Law of one price
LS	Lean season
LSMS-ISA	Living Standards Measurement Study – Integrated Surveys on Agriculture
MODIS	Moderate Resolution Imaging Spectroradiometer
NAERLS	National Agricultural Extension and Research Liaison Service
NASA	National Aeronautics and Space Administration
NASS	National Agricultural Sample Survey
NBS	National Bureau of Statistics
NCC	Nigerian Communications Commission
NDVI	Normalized difference vegetation index
NFRA	National Food Reserve Agency
PP	Phillips-Perron test of series stationarity
PPP	Purchasing power parity
R&D	Research and development
SAFEX	South African Futures Exchange
SSA	Sub-Saharan Africa
TRAINS	Trade Analysis Information System
UN	United Nations
UN Comtrade	United Nations Commodity Trade Statistics Database
UNCTAD	United Nations Conference on Trade and Development
USAID	United States Agency for International Development

USDA	United States Department of Agriculture
USDA-NASS	United States Department of Agriculture National Agricultural Statistics Service
USDA-PSD	United States Department of Agriculture Production, Supply, and Distribution database
WAOB	World Agricultural Outlook Board of the USDA
WASDE	World Agricultural Supply and Demand Estimates of the USDA
WB	World Bank
WFP	World Food Programme

ABSTRACT

Hatzenbuehler, Patrick L. Ph.D., Purdue University, August 2016. Food Security Crop Price Transmission and Formation in Nigeria. Major Professor: Philip C. Abbott.

The three studies in this dissertation explore the current conditions and operations of markets for seven key food security crops (cassava, cowpeas, maize, millet, rice, sorghum, and yams) in Nigeria.

Chapter 2 is an empirical analysis of the current agricultural statistics system in Nigeria. A number of sources gather and report agricultural statistics for the country. Since there has not been an agricultural census implemented there for multiple decades, however, there is no objective source for data verification. Therefore, this study uses two additional types of "on the ground information" to assess if agricultural production estimates reflect growing conditions: prices and remote sensing data in the form of the normalized difference vegetation index (NDVI). The results show that existing production estimates are poorly correlated with both prices and the NDVI. Prices and the NDVI data are highly correlated, however. These findings imply that existing production estimates do not reflect growing conditions, and, therefore, are of poor quality.

Chapter 3 is a comprehensive analysis of crop price transmission from global and neighbor country prices to Nigerian commercial hub and urban markets, and from commercial hubs to other urban and rural markets within the country. The results show that tradability matters for price transmission, but that tradability varies across crops and scopes of markets. Nigerian urban rice prices are highly correlated with prices on global markets and those in neighboring countries. Coarse grain prices appear disconnected from global markets, however, but move closely with those in neighboring countries. Large margins were estimated for prices of rice imported from global markets (in all

regions), and for coarse grains to Southern Nigerian markets only. The existence of large margins implies that there are transactions costs and/or quality premiums that vary systematically with the world price, and/or mark-ups by traders with market power in these markets. While domestic market prices are almost always cointegrated, perfect price transmission is generally found only between commercial hubs and other urban markets. Moreover, long lags were found for price transmission across all scopes of markets, but especially between urban and rural prices in some regions. These results imply that local conditions (e.g., weather) are relatively more important than external market prices for explaining price variation in rural markets, especially in the short-run.

Chapter 4 incorporates NDVI data into price formation models to estimate whether observable growing conditions explain price variation in Nigerian food security crop markets. Four issues related to use of NDVI data that exist within the literature are investigated: whether NDVI is a valid proxy for expected production, how NDVI is a proxy for seasonality, the relationship between market size and the area scope used to average NDVI values across space, and if anomalous harvest expectations can change long-run price variation and price relationships between markets. The results show that information on growing conditions is more informative for isolated than interconnected markets. Even for those local prices, however, other non-weather and non-external market price factors are relatively more important for explanation of price variation.

An implication of these results is that Nigeria cannot plausibly rely solely on direct imports from global markets to meet short-run demand during future weather shock periods. Thus, storage is required to ensure stability of food security, either for imports or domestically produced surpluses acquired in non-crisis periods. Given the isolation of rural markets, local and on-farm stocks are at least as important as large facilities in commercial hubs. Improvement of village level and on-farm storage systems and elimination of other market distortions that inhibit trade between urban and rural markets would make public storage less needed. The findings on poor quality of agricultural statistics indicate a clear priority to improve agricultural data, to facilitate better planning of any food security strategies. A combination of surveys with remote sensed and crowd sourced data may improve feasibility in the funding constrained environment.

CHAPTER 1. INTRODUCTION

1.1 Motivation

The immense potential for food market conditions in Nigeria to substantially impact future food market outcomes (e.g., prices) in West Africa, Africa at large, and the globe becomes clear after looking at the country's current socioeconomic characteristics. The International Monetary Fund (IMF) estimates that Nigeria is both the largest oil exporting country, and has the largest economy in terms of gross domestic product of all countries in Sub-Saharan Africa (SSA) (IMF 2015). While economic growth has slowed in recent years (IMF 2016), Nigeria is likely to remain influential in determining economic conditions in West Africa and throughout the African continent for some time. In addition to its big economic size, the World Bank estimates that, as of 2014, Nigeria has the seventh largest population of all countries in the world, the highest population in Africa, and a population growth rate above 2% per annum, which exceeds that of all developed countries and many other developing countries (World Bank). These current conditions and forecasted trends in income and population growth imply that Nigeria's already large food market size is growing and will continue to grow for some time.

The plausible continued expansion in the size of Nigerian food markets means that it will need to either increase agricultural production from current levels and/or increase imports from international markets to meet current and future domestic food demand. Nigeria has long established links with global food markets to meet its demands for food, especially wheat and rice (Olomola 2013). UN Comtrade data on trade flows also show imports of maize into Nigeria in some years from historically large global market exporters such as the United States and South Africa. Future shocks to global markets in these crops may influence Nigerian market conditions unless there is a substantial change from the status quo in market structure or food policy[1].

In addition to its relatively large economy and population, Nigeria also has a considerable amount of land and natural resources. Nigeria currently accounts for a substantial share of overall West African agricultural production, which makes it particularly influential in determination of food market outcomes in neighboring countries (Elbehri et al. 2013). UN Comtrade data since 2000 show persistent linkages between Nigeria and Niger for trade in cereals (maize, millet, sorghum, and rice), mainly exports from Nigeria to Niger; and, some limited observations of imports by Nigeria from other neighboring countries in West Africa such as Cameroon, Chad, and Burkina Faso[2]. There is also record of rice imports from Benin to Nigeria (CILSS 2015) and anecdotal evidence of substantial rice imports from both Benin and Niger into Nigeria, which are at least in part initiated by traders interested in avoidance of tariffs imposed at Nigerian ports (Johnson and Dorosh 2015). Thus, future shocks to either global markets or Nigerian markets will plausibly spill over and greatly influence food markets throughout West Africa, especially those for tradable cereals.

This influential position of Nigeria to affect West African, and, to a lesser but still significant degree, global food markets implies that Nigeria is a worthy focus country for empirical research that can provide clearer insights into the current conditions and operations of these markets. The present period is a notable one in Nigeria's history with regard to its agricultural policy because it remains in somewhat of an extended limbo state with regard to determination of the role of the Government of Nigeria (GON) in agricultural markets. In the period that followed independence in October 1960, which lasted until the "structural adjustment" period of the late 1980's, direct government participation in agricultural markets was widespread. Government entities were the only institutions involved in the trade and marketing of some agricultural commodities.

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[1] Both Chapter 3 and the recent paper by Johnson and Dorosh (2015) include discussions about how Nigerian trade policies have attempted to limit the degree to which events on global markets influence the domestic market, but these have been poorly implemented in recent years.
[2] The results in Chapter 3 show that the market linkages between Nigeria and its neighboring countries in West Africa appear much more extensive than would be discerned solely from UN Comtrade data.

Government participation in agricultural markets became much more diffuse following structural adjustment, as some of the marketing roles previously implemented by the government were taken over by private sector entities, while the GON maintained control of others (Walkenhorst 2009). The post-structural adjustment period arguably still applies for the current period. The Nigerian Federal Ministry of Agriculture and Rural Development (FMARD) is currently active in some aspects of the agricultural economy, but has a much more indirect influence on commodity marketing than was the case prior to structural adjustment (Olomola 2013).There have been recent efforts by the FMARD to explore reinstatement of marketing boards, though in a more private sector oriented form following the 2007-08 "food crisis". These efforts appear to have not so far led to any substantive changes in government intervention in these markets as a result of this exploration, however.

There are a few key examples of Nigerian FMARD participation in agricultural markets in the current, post-structural adjustment era that are relevant for understanding the current conditions and operations of Nigerian food markets. These include its role in setting trade policies such as tariff rates on imports of agricultural commodities (which have been adjusted intermittently, as seen in UNCTAD Trade Analysis Information System (TRAINS) tariff rate data). Additionally, the FMARD was active in implementation of a mix of trade and direct market intervention policies (e.g., subsidized agricultural production inputs, sale of food), and expansion of existing food storage capacity in response to rising food prices during the 2007-08 "food crisis" (Olomola 2013).

The 2007-08 "food crisis" was described by Olomola (2013) to primarily have impacted Nigeria through the transmission of high prices for imported crops (mainly rice and wheat), and less so due to production shortfalls related to weather. Only the Northern Nigerian region was impacted by extreme weather during that period (Olomola 2013). These observations are consistent with the stylized fact that Nigeria is less at risk of dramatic aggregate shortfalls in food crop production due to its more tropical climate than, for example, its neighbor countries to the north in the Sahel. Short-run shortfalls in local regions, especially in Northern Nigeria, however, do occur and cause intermittent local price spikes.

The mix of consumption, production, and price stabilization related interventions by the FMARD in the wake of the 2007-08 “food crisis” implies that the food insecurity policy responses are primarily aimed toward resource allocation in a context of persistent poverty. It is apparent in the IMF Article IV Consultation for 2016 that poverty remains widespread in the country despite some recent years of relatively high economic growth. Indeed, the IMF estimates the percentage of people in Nigeria in poverty[3] increased from 62% in 1990 to 68% in 2010 (IMF 2016). The large percentage of the population that lives in poverty means that even relatively small price fluctuations can have important effects on welfare of large numbers of people. The observed interventions in some markets through a combination of price stabilization and cash transfers in the wake of 2007-08 “food crisis” (Olomola 2013) implies that most current food security strategies are aimed to address short-run, poverty related fluctuations in food affordability.

Nigeria’s influential position in West African and global food markets and the examples of trade and marketing policy implementation in recent years, make it an ideal candidate for detailed economic policy analyses. Indeed, researchers at organizations such as the International Food Policy Research Institute (IFPRI), among others, have devoted considerable research attention to the trade and marketing of agricultural crops (primarily rice) in Nigeria[4]. The initial goal of this dissertation was to contribute to this emerging literature by producing research that would be of use for agricultural policy design in Nigeria.

1.2 Dissertation Focus and Design

At the outset of this dissertation project, an empirical analysis was proposed that was to estimate whether Nigeria could more cost-effectively meet food security policy goals through trade and/or storage, through market level studies similar to that by Bigman

[3] As measured by the poverty headcount ratio at $1.25 a day (PPP).

[4] Recent IFPRI reports include those by Johnson, Takeshima, and Gyimah-Brempong (2013) on rice production policy effects on market outcomes such as trade flows; and, Johnson and Dorosh (2015) on optimal rice tariffs in the context of porous borders with neighboring countries.

and Reutlinger (1979), while also accounting for the effects of alternative policy regimes on households with different socioeconomic characteristics. This empirical research question was expected to be feasible due to the rich history of agricultural trade and storage policy literature, of which the study by Bigman and Reutlinger (1979) is a part; existing market data from sources such as FAOSTAT and the U.S. Department of Agriculture Production, Supply, and Distribution (USDA-PSD) database; and, newly gathered household data from the Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA) gathered jointly by the Nigerian National Bureau of Statistics (NBS) and the World Bank.

Upon implementation of field work in Nigeria, however, it became apparent that, although such an empirical analysis is implicitly feasible, selection of data among many sources and in the absence of an objective verification institution such as an agricultural census would be problematic. Additionally, upon closer examination of available production estimates, the agricultural data system in Nigeria does not appear to currently have the capacity to provide accurate enough data to be suitable for use in empirical analyses (the subject of Chapter 2). This makes the initially proposed studies better left for future research

These observations on the quality of Nigerian agricultural production data made it apparent that alternative methods were needed to assess current conditions in Nigerian food markets without relying on quantity data. Fortunately, there have been many advances in the economic literature in the past few decades with regard to implementation of price transmission analyses to assess market conditions using price data. Price transmission analyses are informative of market operations because they estimate the degree to which prices in markets co-move, and, thus, whether markets are linked by trade and/or other common factors (Barrett 1996). Since price transmission analyses provide these rich inferences with regard to market connectivity and the factors that influence prices within and across markets, they have been identified as a key prerequisite for food security policy design (Lançon et al. 2011).

A price transmission study targeted to Nigerian markets is a contribution to the price transmission literature that ballooned following the “food crisis” of 2007-08, which includes the recent studies by Minot (2011) and Baltzer (2015). The current understanding of how markets are interconnected within Nigeria was somewhat dated and spotty with regard to regional and crop market coverage. The extensive early analysis of Jones (1968), supplemented by the regional analyses by Hays and McCoy (1978) and Delgado (1986) and others, and recent regional analyses by Okoh and Egbon (2005) and others, do not together comprise a comprehensive assessment of the current organization and conditions of Nigerian agricultural markets. This gap is filled with a comprehensive price transmission analysis that utilizes newly available data (the focus of Chapter 3). Additionally, while there is somewhat of an extensive existing literature of price analyses on Nigerian food markets, there is limited evidence of investigation into other non-external market price local condition factors that might explain price variation in these markets. Remote sensing normalized difference vegetation index (NDVI) data are, therefore, encompassed into the price transmission models to measure the degree to which growing conditions matter for explanation of Nigerian crop price variation (the subject of Chapter 4).

While these studies are not the quantitative policy focused analyses that were initially proposed, the results from these studies have important implications for future food security policy and lay critical groundwork that will enable the initially proposed quantitative agricultural policy analyses to be implemented in the future. These studies also follow a trend in global literature that emerged following the 2007-08 “food crisis” that focused on price transmission, since our ability to build short-run quantity models remains controversial.

With regard to the specific implementation of the studies, the first study, found in Chapter 2, is an empirical assessment of the current state of the Nigerian agricultural statistics system. The quality of Nigerian agricultural statistics has been questioned for some time (see Berry (1984) and Collier (1988) for early discussions, and Jerven (2013) for a recent discussion). Nigeria was recently identified by the Agricultural Market Information System run by the Food and Agricultural Organization of the United Nations (AMIS-FAO) as a strategically important country that was in need of technical assistance for gathering and reporting of agricultural statistics (AMIS-FAO 2015). Chapter 2 includes a comprehensive empirical analysis of the quality of currently available Nigerian agricultural statistics. The results of the analysis, which are summarized below, provide a cautionary tale for any researcher who seeks to implement empirical economic analyses on Nigerian food markets and crucial insights into existing institutional capacity in general.

The second study of this dissertation builds on the recent advances in the price transmission literature. It is a comprehensive price transmission analysis that estimates how well Nigerian urban food prices co-move with those in global and neighbor country markets, as well as the degree to which prices across urban markets and between urban and rural markets within the country correspond with each other. This study's comprehensive design is much more extensive than previous price transmission analyses of Nigerian food markets. It builds on historical studies of Nigerian agricultural market price correspondence such as that by Jones (1968), which found high price correspondence across urban markets in Nigeria for some crops; and, recent studies such as those by Minot (2011) and Baltzer (2015), which found that many SSA country markets are relatively disconnected from global markets compared to countries in other parts of the world. This study was feasible because of newly available data provided by the FAO Global Information and Early Warning System (GIEWS) Food Price Monitoring and Analysis Tool; the World Food Programme (WFP) VAM Food and Commodity Prices Data Store[5]; and, the Nigerian National Bureau of Statistics (NBS). These data were unavailable in the years immediately following the 2007-08 "food crisis" and so in analyses by Olomola (2013) and others, but became available by 2014. The results for this price transmission analysis are discussed below, and are found in Chapter 3[6].

The results from the price transmission studies and recent findings in the study by Baffes, Kshirsagar, and Mitchell (2015) imply that local, non-external market price

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[5] Both GIEWS (http://www.fao.org/giews/pricetool/) and WFP (http://foodprices.vam.wfp.org/Analysis-Monthly-Price-DataADV.aspx) are rich sources of time series price data gathered in many developing country food markets, especially since 2005.
[6] This chapter was accepted for publication in a forthcoming 2016 issue of the *Journal of Agricultural Economics*.

factors such as weather are influential for explanation of price formation over time, especially in rural, isolated markets in the short-run. In order to measure how much growing conditions changes affect prices in Nigerian markets, the third study, in Chapter 4, builds on the innovative methods of Brown and Kshirsagar (2015) and Baffes, Kshirsagar, and Mitchell (2015) and uses NDVI to explain food price variation in Nigeria. The results from this final analysis, which are discussed below and found in Chapter 4, provide insights into the degree to which growing conditions influence prices in Nigerian markets, how important growing conditions are relative to other factors (e.g., external prices), and the relative importance of weather in explaining price variation in areas of Nigeria with different climatic and geophysical characteristics. In addition to the advancements in understanding of factors that influence Nigerian food prices, the study includes a thorough discussion of the linkages between growing conditions and prices based on economic theory. It also includes a comparison of available proxies for expected production: NDVI and rainfall. The empirical analysis investigates four issues that have emerged in the literature: whether NDVI is a valid proxy for expected production, how NDVI is a proxy for seasonality, how economic theory can be used to select area size over which to average NDVI values, and whether growing conditions anomalies can have long-run effects on prices and price relationships through their influence on expectations for upcoming harvest.

The composite of these three studies, therefore, is a dissertation that comprehensively describes the current state of the agricultural statistics system and agricultural crop marketing conditions and operations for seven key food security crops (maize, millet, sorghum, rice, cassava, yams, and cowpeas) in Nigeria. The studies were designed to use methods that take best advantage of available data. Results from these studies have important implications for future food security policy and research in Nigeria and elsewhere. The concluding chapter will explore some of these food security implications.

1.3 Preview of Empirical Results

The results from the empirical analysis of the Nigerian agricultural statistics system in Chapter 2 show that much of the currently available national and state level agricultural production estimates are of poor quality. This determination was made through a comparative analysis that utilized three types of "on-the-ground" information: production estimates from a variety of international and national sources, remote sensing data in the form of NDVI measures, and price data. NDVI and price data are two alternative measures of "on the ground information" that correlate with growing conditions, and, thus, production. Use of these two alternative measures of local conditions to estimate whether agricultural production estimates reflect those conditions is unique to this study. This method to verify agricultural production estimates was needed because there is no other objective verification source. Nigeria has not implemented an agricultural census since before the 1980's, so there is not only an absence of an objective outside verification entity, but also no survey that is comprehensively representative of the entire population of farms from which to obtain a sample (Onyeri 2011). The results in this study showed that the production estimates do not correlate well with either NDVI or prices, but the NDVI and prices correlate well with each other. Thus, it was determined that the production estimates do not well reflect local conditions, and so are of poor quality. Unless additional political will and resources are devoted toward addressing this issue, policymakers will continue to make decisions without an accurate view of the current state of affairs.

Despite the apparent poor quality of the agricultural production quantity data, the results in Chapter 2 showed that the available price data do appear to reflect local conditions. These price data were used in the comprehensive price transmission analysis in Chapter 3, which led to some key insights on the current structure of Nigerian food markets. The first discovery is that crop tradability matters for price transmission, but that tradability varies across crops and scopes of markets. Nigerian urban rice prices were found to strongly co-move with global and neighbor country rice prices, as well as with prices in other urban markets within the country. Nigerian urban coarse grain (maize, millet, and sorghum) prices, however, were disconnected from global markets, but highly correlated with neighbor country prices. These results imply that rice and coarse grain markets are well-connected across West Africa, and urban markets are also linked with global rice markets through port connections in Southern Nigeria. The results of this study also imply that local conditions matter for food prices, but the degree to which local conditions matter varies across crops and scopes of markets. Nigerian urban markets are highly interconnected with each other. For most crops analyzed, they are relatively more highly connected with each other on average than with rural markets. In all markets, however, broadly long lags in the speed of price transmission were found. This implies that some markets, especially rural markets for some crops, are isolated from other markets. Thus, their prices are determined by local factors rather than by prices in external markets, at least in the short-run. The last finding is that there are large estimated margins in prices for rice in markets in all regions of Nigeria, and for coarse grains in Southern Nigerian markets. These large margins imply that there are either large transactions costs or quality differences that vary systematically with the world price and/or mark-ups obtained by traders that import cereals from global markets.

Since the price transmission analysis showed, in general, that there are long lags in the price transmission speed across markets, and most especially rural markets, there must be other local factors that determine prices in these markets besides external prices, especially in the short-run. Thus, the third study in Chapter 4 of the dissertation builds on the methods of Brown and Kshirsagar (2015) and Baffes, Kshirsagar, and Mitchell (2015) by using NDVI data as a proxy for expected production to explain price variation. The results from the study show that the degree to which growing conditions explain price variation in Nigerian markets is broadly low, however. There were some sets of prices, specifically, for crops in localized rural markets situated in regions that are highly dependent on rainfall for precipitation, for which the NDVI data are reasonably informative for price movements. There is also empirical evidence to support the conjecture that expectations formed on the upcoming harvest, especially in the months immediately preceding harvest, can cause the relationships between spatially disparate markets to change over time. Since these changes may persist for some months, the findings that expectations based on growing conditions can have persistent effects on prices, in addition to the established short-run effects found in Chapter 4 and in Brown and Kshirsagar (2015) and Baffes, Kshirsagar, and Mitchell (2015), is a substantive contribution to this literature. The other results in the study are consistent with expectations and provide guidance for future users of these data in empirical analyses, especially with regard to aligning the scope of the remote sensing data with the market size as determined by socioeconomic characteristics (e.g., presence of a large commercial hub).

The results from these studies have important food security implications, especially with regard to the design of future FMARD food policy interventions to respond to short-run disasters and targeted initiatives that can plausibly reduce risk of food insecurity in the long-run. With regard to short-run disaster response, the observed long lags in price transmission across all examined markets and potentially imperfectly competitive markets for imported cereals implies that it is unlikely that importation of cereals from global markets for the purpose of meeting short-run demand during unexpected supply shortfalls would be timely or cost-effective. This means that some storage facilities are needed. These would ideally be operated in parts of the country where they could meet potential demand in rural areas that are most at risk of growing conditions anomalies. Given that there are local markets that are isolated, expansion of village level and on-farm storage would be at least as important as sizable storage facility development in commercial hub since they would lessen the need for isolated markets to meet intermittent short-run demand shocks with outside supplies. With regard to the long-run implications, the findings that other factors besides weather and external prices (e.g., transportation costs from urban to rural markets) determine prices in isolated markets mean that there are existing market structural factors that are limiting urban and rural market connectivity. Policy efforts that clearly identify and directly address these distortions would improve food availability and affordability in both disaster and non-disaster periods, and reduce poverty in the long-run. Further details on the food security implications of the results from this dissertation, and recommendations for future studies are provided in the conclusion (Chapter 5).

CHAPTER 2. EMPIRICAL ASSESSMENT OF THE CURRENT NIGERIAN AGRICULTURAL STATISTICS SYSTEM

2.1 Introduction

Uncertainties with regard to global food supplies and prices during the 2007-08 "food crisis" prompted the Group of Twenty (G-20) to make efforts to improve global and individual country agricultural statistics and information systems. The Agricultural Market Information System, based in the Food and Agriculture Organization of the United Nations (AMIS-FAO), was established as a result of this G-20 focus on the issue, and was provided with a mandate to improve existing data and expand institutional capacity of country statistics agencies (G-20 2011). Nigeria was identified as a key developing country, and the only focus country in Africa, that received technical support and capacity development assistance to improve existing agricultural information systems (AMIS-FAO 2016a).

AMIS-FAO and its partners, such as the Bill and Melinda Gates Foundation, have a difficult task, because the current agricultural statistics system in Nigeria appears to be in poor condition in many regards. Questions with regard to the quality of Nigerian agricultural statistics have been asked for some time. Discrepancies in values of reported Nigerian agricultural statistics across sources were identified by Berry (1984) and Collier (1988), and divergent estimates across sources remain today (AMIS-FAO 2014).

In such a setting of multiple, contradictory reported estimates, it is desirable to identify an objective source that can intermittently provide verification across sources. The FAO has served such a verification role in many developing countries, through its organization and provision of technical assistance associated with implementation of an agricultural census, which is meant to occur in all countries at least once each decade (FAO 2015). Such an agricultural census, however, has not been conducted in Nigeria since before the 1980's (Onyeri 2011).

This problematic situation in Nigeria has important implications for agricultural markets and the livelihoods of participants in those markets. Recent empirical research shows evidence that the release of official agricultural production estimates in the U.S., such as those reported in the U.S. Department of Agriculture World Agricultural Supply and Demand Estimates (WASDE) reports, has pronounced effects on market outcomes, including prices (Adjemian 2012). These findings support a long history of economic theory and empirical observations, much of which built upon the Working (1958) anticipatory price model, which describes how agricultural market outcomes such as prices continually adjust as expectations of market actors on future supplies and demand are updated over time. If the information with which the market participants form expectations is poor, as appears to be the case currently in Nigeria, then overall economic welfare is lower than its potential. This is because over the short-run, consumers consume too little and producers and/or traders store too much, or vice versa (Hayami and Peterson 1972).

The discrepancies in Nigerian agricultural data identified by Berry (1984) and Collier (1988), and highlighted by Jerven (2013), are also problematic for agricultural development and policy. If there is disagreement on baseline conditions that existed prior to policy implementation, then it is impossible to accurately measure the impacts of the policy on market outcomes and welfare (Blandford 2007).

Even though data in general are of poor quality in many developing countries, these data are still commonly used in policy decisions that influence resource distribution and livelihoods (Jerven 2013). The use of data of questionable quality in advocating policy agendas is not limited to developing country policymakers. The World Bank (2007) cited empirical research that used FAOSTAT data, which rely heavily on developing country official sources such as the Nigerian National Bureau of Statistics (NBS), to argue that the broad trade liberalization policy it promoted would increase overall global agricultural output. Additionally, Fuglie and Wang (2012) used FAOSTAT data to advocate for increased research and development (R&D) funds because they found statistical evidence of a positive relationship between R&D funds and agricultural output. In the Nigerian context, Olomola (2013) cited Central Bank of Nigeria (CBN) data on agricultural production, which show an uninhibited upward trend over time and are found in this paper to be clear outlier estimates relative to those of all other sources. Hence, it is poor evidence that Nigerian farmers responded to higher prices and policy interventions that followed the 2007-08 "food crisis" with increased output. These are just a few examples of how data of uncertain quality can be used by policymakers and researchers in a manner that has a profound impact on policy debtes and current and future livelihoods of people throughout the world.

In the food security field, agencies such as the Famine Early Warning System Network (FEWS-NET) and the World Food Programme (WFP) have recently invested substantial resources toward improvement of developing country agricultural information systems, including in Nigeria. It is telling, however, that FEWS-NET and WFP primarily have focused on the gathering of information that is quite different from agricultural statistics that are estimated from farm surveys (e.g., agricultural production). FEWS-NET primarily uses remote sensing data and enumerator obtained price data to monitor short-term market conditions. The WFP has invested heavily in the systematic gathering of food prices in many developing country markets over time, which are reported through the online VAM Food and Commodity Prices Data Store. The observation that FEWS-NET and WFP have focused primarily on gathering price data, and remote sensing information to a lesser degree[7], implies that these sources do not find sufficient value in current agricultural production data for their short-term food security monitoring activities. This is plausibly because of data quality concerns, and also because, much developing country agricultural statistics are often not reported on a time line that is helpful for response to intra-crop year changes in local conditions. The most recent Nigerian agricultural production estimates from NBS, for example, are from 2012.

In light of these issues, this study assesses the current state of the Nigerian agricultural statistics system in an objective manner. To do so, the methods employed herein use multiple types of "on the ground" information to verify whether existing data are consistent with local conditions. It then proposes a potential path forward for

[7] The WFP recently considered the use of remote sensing data to supplement its price tool, as proposed in Brown, Tarnavsky, and Bonifacio (2015), but this has not to present knowledge been adopted.

improvement of the Nigerian agricultural statistics system within the context of limited financial resources.

The study includes a detailed description of the current agricultural data system, and a thorough empirical analysis of the quality of reported data. The empirical analysis is designed to calculate the degree of correlation between: 1) cross-source estimates of agricultural production and yield reported by international, national, and state level sources; 2) estimates of agricultural production and yield at national and state scopes with associated remote sensing data (in the form of the NDVI data); 3) estimates of agricultural production and prices (another key source of on the ground information); and, 4) estimates of NDVI data with prices. It then uses these correlation estimates to compare the degree to which source estimates co-move over time, and whether the three measures of local conditions (production estimates, prices, and NDVI data) are correlated with each other.

The results of the analysis show that the current state of the Nigerian agricultural system appears dire. While there has been some apparent cooperation across sources over time, this cooperation broke down in years when surveys were implemented, and then the preceding data were not subsequently revised as is done elsewhere. This is observed in breaks in data series in which estimates are substantially different from previous estimates. There is also little information provided in available metadata documentation on how the data that were reported in non-survey years were obtained. In the absence of an agricultural census, it is impossible to know whether the data that precede the implemented surveys or those obtained from survey implementation are more accurate. Correlations between agricultural production and yield, at both the national and state levels, and NDVI data are broadly quite low, with only a few key exceptions. Additionally, there is poor correspondence between state level production estimates and prices. The estimates for only one of four analyzed states were somewhat encouraging with regard to co-movement of production estimates and prices. Both urban and rural price data, however, correspond well with NDVI data. The findings of the production estimates not corresponding well with two independent sources of on the ground information (prices and NDVI data), but the two independent sources corresponding well with each other, implies that the production estimates broadly do not reflect well local conditions. This is plausibly because most of the available data are only sparsely obtained from surveys. Additionally, the surveys that were implemented are implausibly representative of aggregate agricultural conditions since the sample estimates scaled up to obtain aggregate estimates did not come from an agricultural census or similarly all-inclusive tool, nor large samples. In light of these results, ideas for additional studies aimed to determine an optimal mix of new technologies and surveys that can obtain high quality data at a minimal cost are proposed in the concluding remarks.

2.2 Overview of the Nigerian Agricultural Statistics System

There are multiple state, national, and international sources that gather and report agricultural production estimates for Nigeria[8]. It is commonplace for these sources to rely on information from each other, mainly because implementation of farm surveys appear to only occur intermittently, and in a manner that is not comprehensive.

2.2.1 State and national government sources

The Nigerian FMARD has the legislative mandate for gathering and reporting agricultural statistics in Nigeria (Onyeri 2011). One way the FMARD appears to have chosen to fulfill its mandate is through dissemination of the "Agricultural Production Survey" reports through the National Programme for Agriculture and Food Security (NPAFS), a department of the FMARD. The metadata descriptions of these "surveys" imply that these are essentially aggregations of state level data gathered by agricultural development projects (ADP) and other state ministry of agriculture institutions. The World Bank initially established ADPs in the 1970's as pilot program agricultural extension agencies in a select few rural areas in Nigeria. The success of these efforts led to the eventual establishment of independent ADPs in each state, managed under the authority of the state ministries of agriculture. Today, the ADPs serve as the primary agricultural extension agencies in the country, and also a primary source of agricultural data (IEG 2012). Unfortunately, it is not possible to determine in the most recent NPAFS

[8] Some sources of agricultural data in Nigeria gather a variety of agricultural statistics (e.g., input prices, market prices), but this analysis focuses solely on production, area, and yield estimates.

report (NPAFS 2010) which production data are from ADPs and/or other departments in the state ministries of agriculture. This implies ADP data from some states are unavailable and/or unreliable.

Another way in which the FMARD has met its agricultural statistics reporting mandate is through dissemination of agricultural performance reports that are produced by the National Agricultural Extension and Research Liaison Service (NAERLS), another department of the FMARD, in cooperation with Ahmadu Bello University and other national government ministries (the partner ministries appear to vary over time). While the NAERLS has actively reported crop production estimates for over 20 years, the most recent reports are disseminated less frequently than in the past, and are only presently online for a relatively few years (2009-13)[9] (AMIS-FAO 2014). The most recent NAERLS report from 2013, describes how NAERLS relied on ADP and/or other departments of state ministries of agriculture for the data in its 2009-12 reports, but then implemented its own farm surveys in 2012 for its 2013 report. The 2012 survey appears to be relatively small, however, especially for such a large country as Nigeria. In total, four communities in each state (36 states and the Federal Capital Territory (Abuja) in Nigeria) and 5 farms in each community (740 total households) were surveyed. These survey data are described in the metadata section of the 2013 NAERLS report to have been compared with ADP and state ministry of agriculture production estimates, but the reports do not describe which, if any, estimates were revised based on these comparisons (NAERLS and FDAE 2013).

While FMARD has made these efforts to fulfill its mandate to report Nigerian agricultural statistics, the Nigerian National Bureau of Statistics (NBS) is plausibly a more familiar data reporting institution for users of these data, because its data are for a longer time series and are accessible online[10]. NBS has also relied heavily on ADP

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[9] There is also a 2006 report on the NAERLS website (http://www.naerls.gov.ng/site2/), but this only includes relatively sparse descriptions of percentage increases (no decreases) of crop area planted and production rather than raw data.

[10] NBS data are available on both the NBS Data Portal website (http://nigeria.opendataforafrica.org/), and the Nigeria CountrySTAT website (http://www.countrystat.org/home.aspx?c=NGA). While both websites have the same agricultural estimates through 2006, the CountrySTAT website provides estimates through 2012 with some associated metadata documentation.

estimates for its production estimates in the past, but has implemented independent farm surveys in some years. NBS is, thus, both a reporter and primary source of agricultural data. From 1994-2003, NBS relied solely on ADP and state ministry of agriculture data (it is unclear when, and in which states NBS relied on one or the other). NBS then implemented surveys, called the National Agricultural Sample Survey (NASS), in 2004-06, in collaboration with the CBN and the Nigerian Communications Commission (NCC) (Okoukoni 2007), and in 2010-11 (CountrySTAT). These surveys are potentially more extensive than the 2012 NAERLS survey. Onyeri (2011) describes the NASS to include surveys of a standard sample size of 5 crop farming households within rotated enumeration areas in all 774 Local Government Areas. This implies that a total of 3,780 potential crop households were surveyed. Documents in the metadata section on the Nigeria CountrySTAT website show that NBS implemented a NASS in 2010-11, which is presumably how the most updated estimates for agricultural production for 2010 and 2011 were obtained[11]. By implication, NBS data for the non-survey years of 2007-09 and 2012 are either forecasts based on data from previous surveys and/or compilations of ADP and state ministry data (as in past reports for 1994-2003). The CountrySTAT metadata documents, apparently obtained directly from NBS[12], however, do not allow for clear determination of the origin of the non-survey year data.

NPAFS, NAERLS, and NBS each report individual state agricultural production estimates. National production estimates are then a summation of these individual state estimates. Reliability of the national production estimates for these national government sources, therefore, inherently depends on the quality of individual state level estimates.

In addition to its collaboration with NBS on its NASS, CBN also reports agricultural production estimates within their annual report on overall CBN operations (CBN 2012). The CBN annual reports, however, unlike the other national sources, only include national production estimates rather than both state and national estimates. It is indeterminate, therefore, whether CBN national production estimates are a summation of

[11] The links to the metadata documents for the 2010-11 NASS are unfortunately not currently operational on the CountrySTAT website.
[12] Some of the metadata documents on the CountrySTAT Nigeria are the same as those obtained directly from NBS during field work.

state level estimates or independent national estimates. These data do vary widely from those of the other national sources, however, as shown in the data description section.

2.2.2 International sources

Numerous international sources also report national production estimates for Nigeria. These sources include the United States Department of Agriculture (USDA) through its Production, Supply, and Distribution (USDA-PSD) online database, and the FAO through both its Statistics Division and associated FAOSTAT database and the recently established AMIS-FAO database[13]. USDA and FAO have staff in Nigeria who coordinate with domestic government statistical agencies and other stakeholders to obtain agricultural statistic estimates (Paulino and Tseng 1980; Vogel and Bange 1999).

Another international source for information on agricultural production conditions in Nigeria is the Famine Early Warning Systems Network (FEWS-NET) of the United States Agency for International Development (USAID). Through its country office in Nigeria, FEWS-NET releases annual "Food Security Outlook" reports, and intra-annual updates, that provide useful information on current growing conditions, as well as general overviews of Nigerian crop season timelines for key food security crops. These FEWS-NET outlook reports rely on weather information from a variety of sources, in addition to price data obtained from ground-based enumerators (FEWS-NET 2016).

The USDA and FAO utilize similar non-farm survey information (e.g., rainfall data) to make their forecasts for Nigerian agricultural production. USDA-PSD production estimates rely on expertise of foreign agricultural attachés, who gather information from a variety of sources (Paulino and Tseng 1980) and remote sensing (primarily that from satellites) information (Vogel and Bange 1999; Becker-Reshef et al. 2010). Satellite imagery is commonly used to adjust estimates obtained from domestic sources and in forecasting (Becker-Reshef et al. 2010). This is justified based on a well-established positive relationship between metrics of vegetation growth, such as the NDVI, and survey-based estimates of agricultural yield and production (Rasmussen 1992; Singh et al. 2002; Funk and Budde 2009). It is unclear whether Nigerian national government

[13] AMIS-FAO estimates differ from those from FAOSTAT because they are on a crop year basis (AMIS 2016b), while those from FAOSTAT are by calendar year (FAOSTAT 2015b).

sources use these types of outside information to form their production estimates. NAERLS reports include descriptions of rainfall data in some years, but it is unclear from the reports if and/or how these rainfall data are used for adjustment of agricultural production estimates.

Table 2-1 below includes a list of these national and international sources with periods of availability of estimates, descriptions of the extent of data availability online, explanations of whether state estimates are reported in addition to national estimates, identifications of the primary data sources, and accounts of whether outside information (e.g., NDVI and/or rainfall data) is taken into consideration in the formation of estimates. It is observed in table 2-1 that data are available for the longest time series from USDA-PSD and FAOSTAT. The international sources (USDA-PSD, AMIS-FAO, and FAOSTAT) and NBS, via the CountrySTAT website, provide more accessible data due to their better online availability than NPAFS, NAERLS, and CBN. The international sources, however, only provide national level estimates rather than both state and national estimates like NBS, NPAFS, and NAERLS. Most of the national sources have relied on ADPs and state ministries of agriculture for their information in some years, and in the case of the NPAFS, these state government institutions are the sole sources of base data. The international sources are the only sources for which it is clear that non-survey information is included in the formulation of their estimates based on information in metadata documents.

Table 2-1: Sources for Nigerian agricultural production estimates with associated characteristics

Source	Period of availability (online)	State level estimate provided also? [14]	Primary sources	Use non-survey information (e.g., weather)?
NBS/ CountrySTAT	1995-2012 (1995-2006 on NBS website[15]; all on CountrySTAT website)	Yes	For 1995 – 2004: ADPs and state ministries of agriculture; for 2004-2006: surveys; For 2006-2009: ADPs and FMARD; for 2010-12: surveys	Uncertain
NPAFS	1999-2009 (none)	Yes	ADPs	Uncertain
NAERLS (with NPAFS et al.)	2008-2013 (in annual reports)	Yes	Surveys and ADPs	Yes
CBN	2002-2011 (in annual reports)	No	Cite NBS as source;	Doubtful
AMIS-FAO	2000-2015 (all)	No	NBS	Uncertain
USDA-PSD	1960/61-2015/16 (all)	No	national sources and non-survey information	Yes
FAOSTAT	1961-2015	No	national sources and non-survey information	Yes

Note: NBS is the National Bureau of Statistics; NPAFS is the National Programme for Agriculture and Food Security, a department of the Federal Ministry of Agriculture and Rural Development (FMARD); NAERLS is the National Agricultural Extension and Research Liaison Service, a joint entity of Ahmadu Bello University and FMARD; CBN is the Central Bank of Nigeria; AMIS-FAO is the Agricultural Market Information System of the Food and Agriculture Organization of the United Nations; USDA-PSD is the Production, Supply, and Distribution (PSD) Online database of the U.S. Department of Agriculture; and, FAOSTAT is the database of the FAO Statistics Division.

2.2.3 The (absent) agricultural census

Since users of Nigerian agricultural data have a choice among the national and international sources in table 2-1, it would be beneficial to have an objective, independent entity that could verify these estimates. In many countries, the FAO has served this verification role through its advocacy and support for implementation of an "agricultural census" each decade. In facilitation of these efforts, the FAO provides technical support

[14] To the author's knowledge, no ADP state level agricultural statistics estimates are available online.
[15] NBS data downloaded from the NBS "Data Portal" website in 2014 were for the period 1994-2005. These were subsequently downloaded in 2015, but for the period 1995-2006. Those downloaded in 2016 are the same values as downloaded in 2014, but all shifted up one year (i.e., 2005 estimate downloaded in 2014 is the 2006 estimate as of 2016). No explanation is provided on the website for this adjustment, which appears to be a fundamental error.

and partial funds to implement a comprehensive farm survey using existing best practices. In some developing countries, the agricultural census is the only sources of primary agricultural statistics (FAO 2015a).

Unfortunately, the available literature suggests that the last time Nigeria implemented an agricultural census was before the 1980's. There is record of a failed agricultural census in 1993, from which no data were released (Onyeri 2011). Additionally, the most recent attempt at implementation of an agricultural census in 2007 was never expanded beyond a limited pilot scale because the FMARD and NBS, which were to partner with FAO to implement the census, did not provide counterpart funding to match that of international donors (Onyeri 2011).

Figure 2-1 shows an amended and supplemented hypothetical data verification pathway of Kasnakoglu and Mayo (2004), in order to characterize how agricultural production data could be verified in Nigeria. In such a verification process, a comparison of estimates from different sources is conducted at each step along the data report pathway. For example, a foreign user can calculate the difference ($\Delta q_{b,c} = q_b - q_c$) between a national estimate (q_b) and international estimate (q_c). If $\Delta q_{b,c}$ is large, then the divergence is either due to consultation of independent survey estimates and/or non-survey information, and/or poor coordination between the national and international sources. A comprehensive agricultural census administered by the FAO, and independent of any other survey, would be, thus, a critical piece of a reliable verification process since it provides a trustworthy benchmark upon which to compare individual source estimates. In the absence of an agricultural census, the foreign user is left with a choice among sources, but no objective guidance for making a selection.

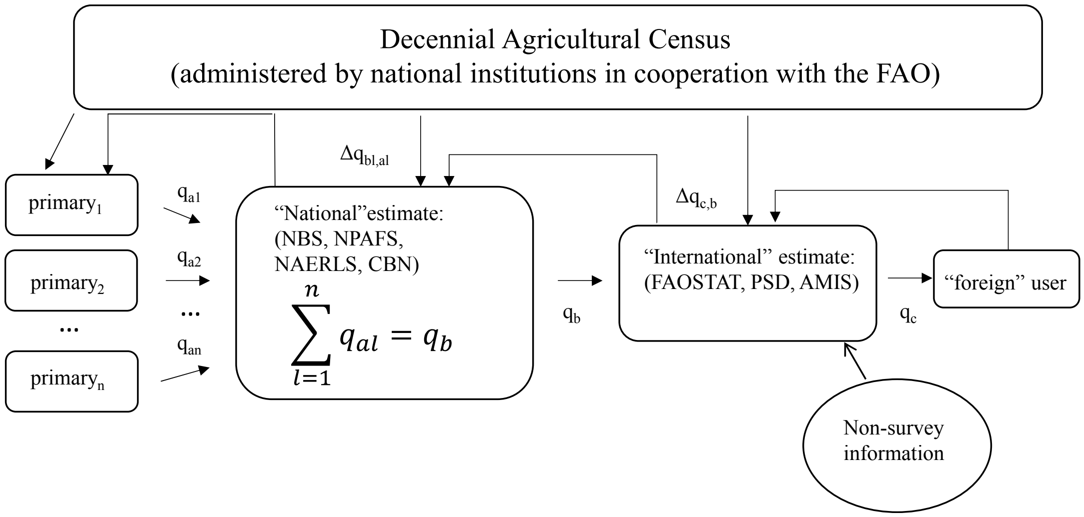

Figure 2-1: Hypothetical verification pathway for Nigerian agricultural production estimates

Note: figure adapted from Kasnakoglu and Mayo (2004).

Another key reason why the absence of an agricultural census presents difficulties for obtaining accurate production estimates is because the agricultural census is a standard tool used by agricultural statistics agencies in many countries to establish sampling frames that are representative of a farm population for use in farm surveys (David 1998). Since an agricultural census is meant to account for all units within a population (e.g., an area, or list of registered farms in an area), the best possible sample of units thus comes from a census because it is comprehensive by definition (David 1998). Since estimates of a given statistic in a sampling frame are composed of individual unit estimates within that frame (House 2001), in the case of Nigeria, which has not implemented an agricultural census in many years, there is no basis on which to combine individual unit estimates to obtain a representative and accurate aggregate estimate.

2.2.4 Summary of current production statistics

With little instruction from an independent authority with regard to the relative validity of estimates reported by the sources described above, other methods are needed in order to assess the quality of the estimates. In order to provide an initial view of how national agricultural production estimates for these sources have varied over time, summary statistics and plots are provided for seven key Nigerian food security crops:

maize, millet, sorghum, rice, cassava, yams, and cowpeas[16]. Table 2-2 below includes summary statistics for estimates of national agricultural production for each of these crops and sources for the period 2000-09[17].

It is observed in table 2-2 that the mean values and variation measures diverge quite widely for some crops across sources. The mean values for rice for AMIS-FAO, USDA-PSD, and NPAFS (and to a lesser extent FAOSTAT) are substantially below those for NBS and CBN. The CBN mean values for the coarse grains (maize, millet, and sorghum) are clear outliers relative to the other sources. The maize USDA-PSD and FAOSTAT (and AMIS-FAO for maize) mean values are close to each other, and somewhat close to the NBS and NPAFS estimates, which are also close to each other. The mean values of these two pairs of sources diverges widely, however, for millet and sorghum, with the international sources reporting substantially higher mean production than the national sources. Mean estimates for cassava and yams are somewhat similar across sources, but there is a disparity in variation metrics across sources. NPAFS has substantially higher variation measures than both NBS and FAOSTAT (and to a lesser degree CBN) for both cassava and yams. The cowpea mean values are somewhat notable relative to all other crops in that the mean values are divergent across all sources. The CBN estimate for cowpeas, however, is again a clear outlier relative to the other sources, as it was for coarse grains (and to a lesser extent rice).

[16] See Terpend (2006), for example, for descriptions of how these crops are widely produced and key to food security in Nigeria and throughout West Africa.

[17] The estimates were limited to a shorter period for the summary statistics than the figures (which extend through 2013) in order to allow for clearer cross-source comparison. This is because NPAFS estimates end in 2009. NAERLS estimates were excluded from the summary statistics, data plots, and later empirical analysis because they are only available online for a relatively short period (2008-13). It was described above, however, that these data are likely similar to the NPAFS for each of these years except 2012 when NAERLS implemented its own survey because they have similar methods described in the metadata sections of their reports. Careful examination of these data confirm that NAERLS and NPAFS estimates are the same for some years and some crops.

Table 2-2: National and international source estimates of Nigerian national crop production for 2000 – 09

	AMIS-FAO	*USDA-PSD*	*FAOSTAT*	*NBS*	*NPAFS*	*CBN*
			Rice[18]			
Mean	1,906	2,082	2,274	2,487	1,950	2,779
Std. Dev.	169	317	304	710	454	456
CV	0.09	0.15	0.13	0.29	0.23	0.16
			Maize			
Mean	6,102	6,442	5,903	6,070	5,937	10,776
Std. Dev.	1,558	1,537	1,221	1,265	1,617	1,828
CV	0.26	0.24	0.21	0.21	0.27	0.17
			Millet			
Mean	…	5,722	6,743	4,294	4,060	7,709
Std. Dev.	…	939	1,267	269	318	1,171
CV	…	0.16	0.19	0.07	0.08	0.15
			Sorghum			
Mean	…	9,105	8,162	5,041	5,173	10,976
Std. Dev.	…	1,504	1,348	341	626	1,584
CV	…	0.17	0.17	0.07	0.12	0.14
			Cassava			
Mean	…	…	38,545	32,399	35,818	38,642
Std. Dev.	…	…	5,089	3,735	8,851	7,222
CV	…	…	0.13	0.12	0.25	0.19
			Yams			
Mean	…	…	30,778	26,168	26,916	29,485
Std. Dev.	…	…	3,630	1,759	5,359	4,347
CV	…	…	0.12	0.07	0.20	0.15
			Cowpeas			
Mean	…	…	2,587	1,704	1,377	4,735
Std. Dev.	…	…	340	318	179	708
CV	…	…	0.13	0.19	0.13	0.15

Note: the units for means and standard deviations are in 1,000 MT. AMIS-FAO is the Agricultural Market Information System of the Food and Agriculture Organization of the United Nations (FAO). USDA-PSD, is the reported value of the U.S. Department of Agriculture Production, Supply, and Distribution (PSD) Online. FAOSTAT are estimates provided by the FAO Statistics Division. NBS estimates are those from the Nigerian National Bureau of Statistics. NPAFS estimates are from the National Programme for Agriculture and Food Security of the Nigerian Federal Ministry of Agriculture and Rural Development (FMARD). CBN estimates are those from the Central Bank of Nigeria.

[18] Rice production is reported by FAOSTAT as paddy rice, but as milled rice in USDA-PSD. It is assumed that NBS, NPAFS, and CBN rice estimates are for paddy rice also. Thus, paddy rice production estimates for FAOSTAT, NBS, NPAFS, and CBN were multiplied by a standard conversion factor of 0.67, as recommended by the Africa Rice Center (2007), to obtain milled equivalent measures.

To see how these estimates have adjusted over time, these production estimates were plotted in figures 2-2 through 2-5 below for the period of 2000-13. While table 2-1 shows that AMIS-FAO, USDA-PSD, and FAOSTAT have reported estimates through 2015, the plots only extend to 2013 to provide insight into the behavior in the estimates one year beyond 2012, the year for which the most recent national source estimate is available. This was done under the understanding that USDA-PSD and FAOSTAT estimates are based primarily on national source estimates, and so any reported estimates by these sources for years in which domestic source estimates are unavailable are forecasts based on the most recently available domestic source estimate and supplemental information.

Figure 2-2 below includes a plot of the estimates of rice and maize production over time for the various national and international sources. Immediately noticeable is that the CBN (and NPAFS to a lesser degree) estimates for rice and maize simply follow a steady upward trend from a base estimate. CBN is also the only source for which there is not a downward estimate that follows a previous estimate for any years. Implicitly this means that CBN and NPAFS data do not encompass non-survey information such as NDVI or rainfall data that reflect inter-annual vegetation fluctuations, and, therefore, are unlikely to reflect conditions on the ground.

Maize estimates move together reasonably well for all sources, except for the obvious outlier estimates of CBN, for much of the period except for the most recent estimates. Readers may question the inclusion of CBN data given its apparent outlier status. These data are included only because they have been used in the recent literature (e.g., Olomola 2013) as evidence that farmers in Nigeria responded to price increases and policy incentives during the “food crisis” period of 2007-08. The apparent consensus maize estimate between AMIS-FAO and USDA-PSD that is observed for recent years for rice does not apply for maize.

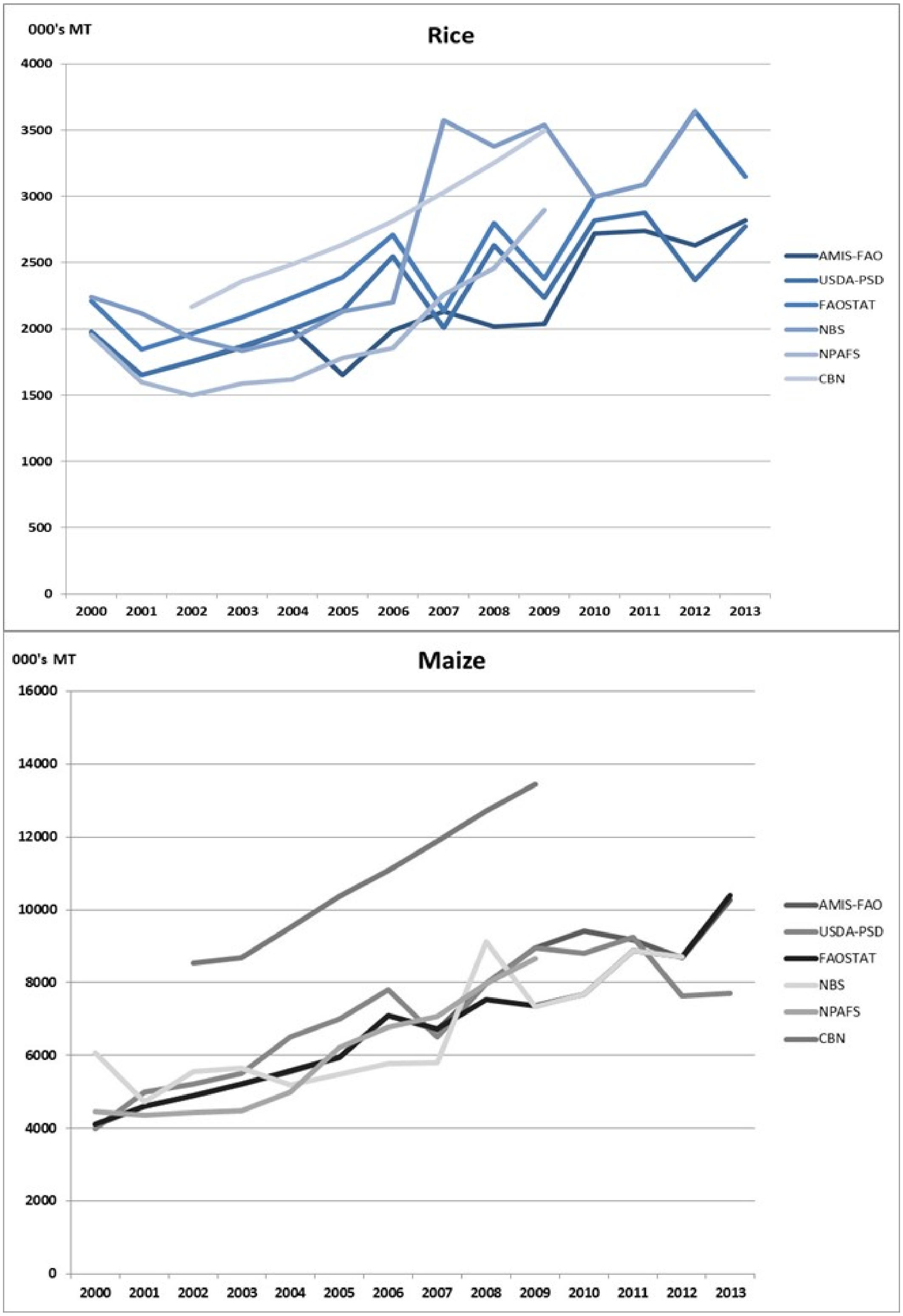

Figure 2-2: Nigerian rice and maize production estimates across sources for the period 2000-13

Figure 2-3 includes plots of millet and sorghum production estimates over time. Similar to the nature of the CBN estimates for maize and rice, there is an uninterrupted upward trend from a base estimate for CBN millet and sorghum estimates as well. For both millet and sorghum, it is observed that the international sources did not follow the national sources for much of the observation period. USDA-PSD estimates for millet converged to the NBS and NPAFS estimates around 2005, but then diverged again by 2012 and 2013. Both USDA-PSD and FAOSTAT sorghum estimates converged toward the NBS and NPAFS estimates around 2009, and have followed them since.

It is apparent in the millet plots that there was a “rebasing” of estimates by 2011. This NBS “rebasing” resulted in a sharply reduced 2011 estimate that was less than 25% of the 2010 estimate magnitude. The international sources appear to have trusted this rebased millet estimate for 2011, but then USDA-PSD returned to its prior level by 2012 and FAOSTAT did so by 2013.

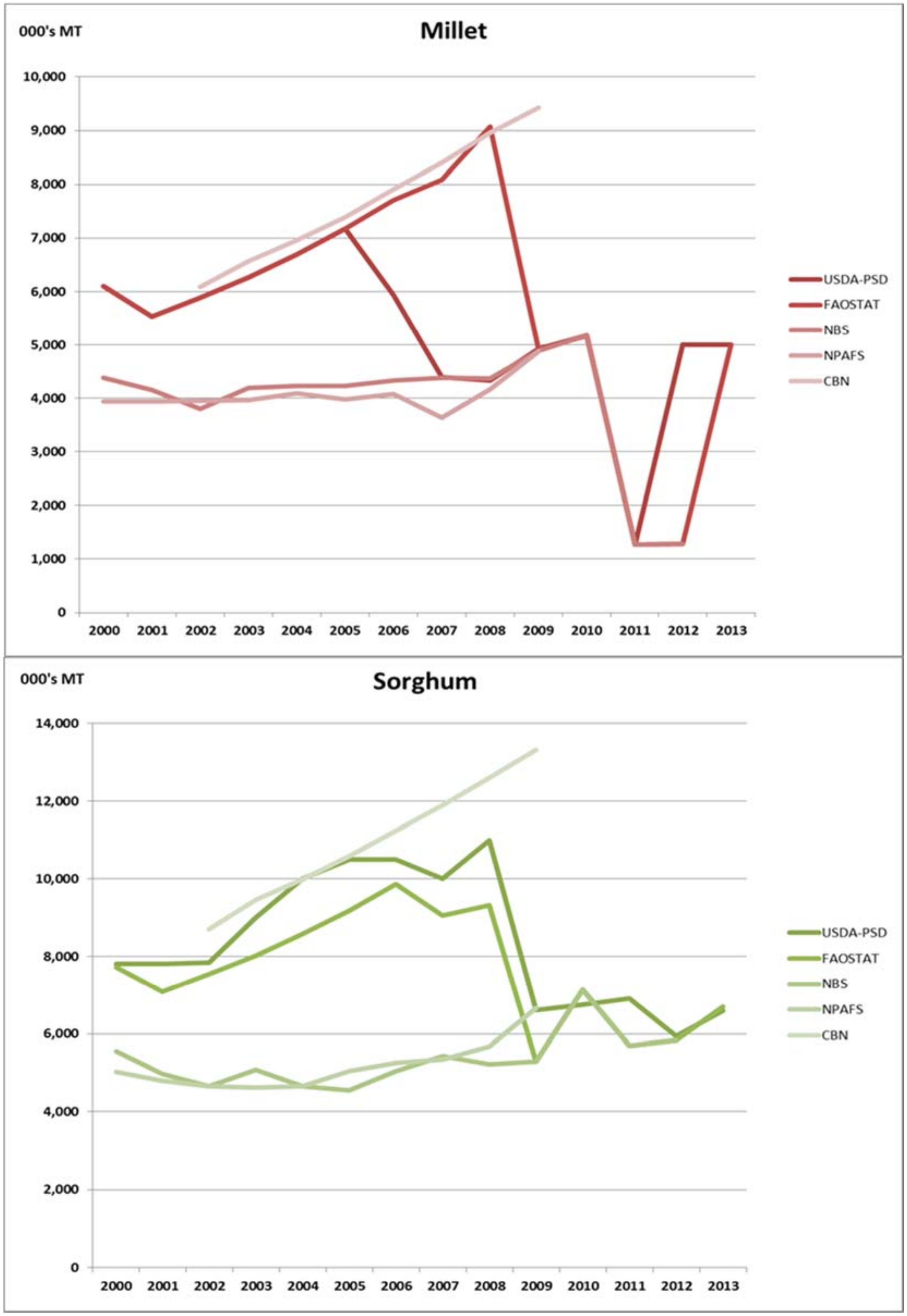

Figure 2-3: Nigerian millet and sorghum production estimates across sources for the period 2000-13

Figure 2-4 below includes plots of production estimates for cassava and yams over time. Although the CBN estimates for cassava and yams are not clear outliers as they were for maize, they do have the same characteristic of unimpeded upward trends as was the case for all other crops. Similar to the millet and sorghum estimates, the FAOSTAT cassava and yams estimates converge to the NBS estimates by 2009. The NBS estimate for cassava and yams was below that of NPAFS beginning in 2004 (the first year for which NBS was reported to implement its own surveys) but then achieved the NPAFS 2009 estimate by 2012. The recent yams estimates show that the FAOSTAT estimates diverged from those of NBS by 2012, and then showed a steep upward forecast for 2013. This could be explained by FAOSTAT utilization of outside non-survey information, but the recent sharp divergence is somewhat surprising given that FAOSTAT and NBS estimates for yams were identical for 2009-11.

Figure 2-5 includes a plot of cowpea production estimates over time. It is immediately clear that the FAOSTAT estimate was substantially higher than that of NBS and NPAFS for much of the observation period, but then converged to the NBS value by 2009 (as was done with all other crops except rice). This, however, does not continue beyond 2012, as the FAOSTAT estimate reflects a sharply lower 2013 estimate that is less than 60% of the magnitude of that of 2012[19]. This could potentially be explained by events on the ground, but the volatility in the NBS cowpea estimates from 2009-12 means that FAOSTAT officials are likely skeptical of the apparent upward "rebasing" of cowpea production estimates by NBS in 2012. The CBN estimates for cowpeas are a distinct outlier, as was the case with maize, but maintain the unabated upward trend as was the case for other crops.

[19] Berry (1984) described even larger fluctuations in agricultural production that resulted from implementation of surveys by the Nigerian Federal Office of Statistics (the predecessor to NBS) in the 1960s. The estimates obtained from surveys were a meagre 10% of the average level of the estimates from years prior to the survey. Berry (1984) argued that the poor quality of the surveys were the problem, but it is just as conceivable that prior estimates to which the survey estimates were compared were equally or more problematic.

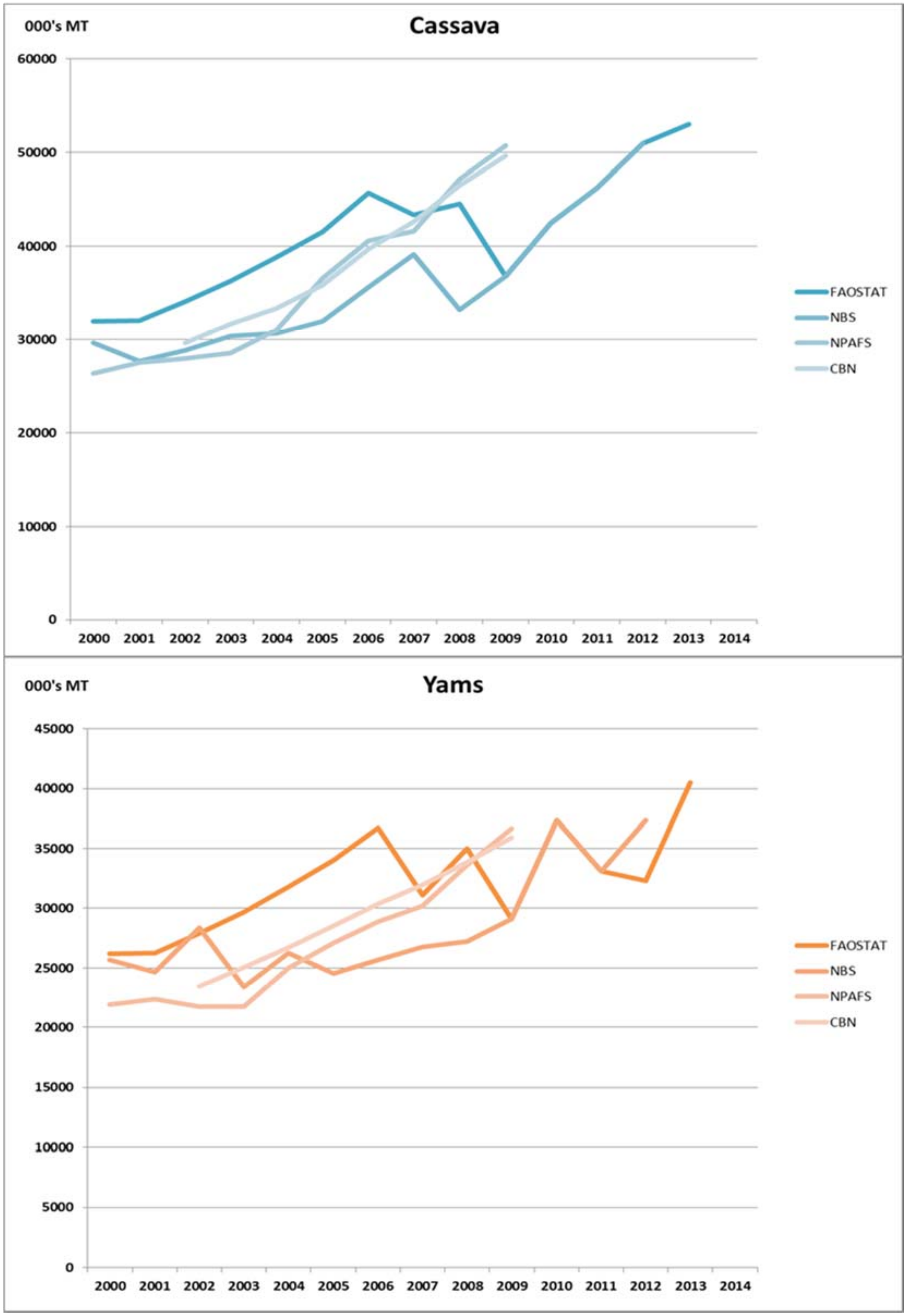

Figure 2-4: Nigerian cassava and yams production estimates across sources for the period 2000-13

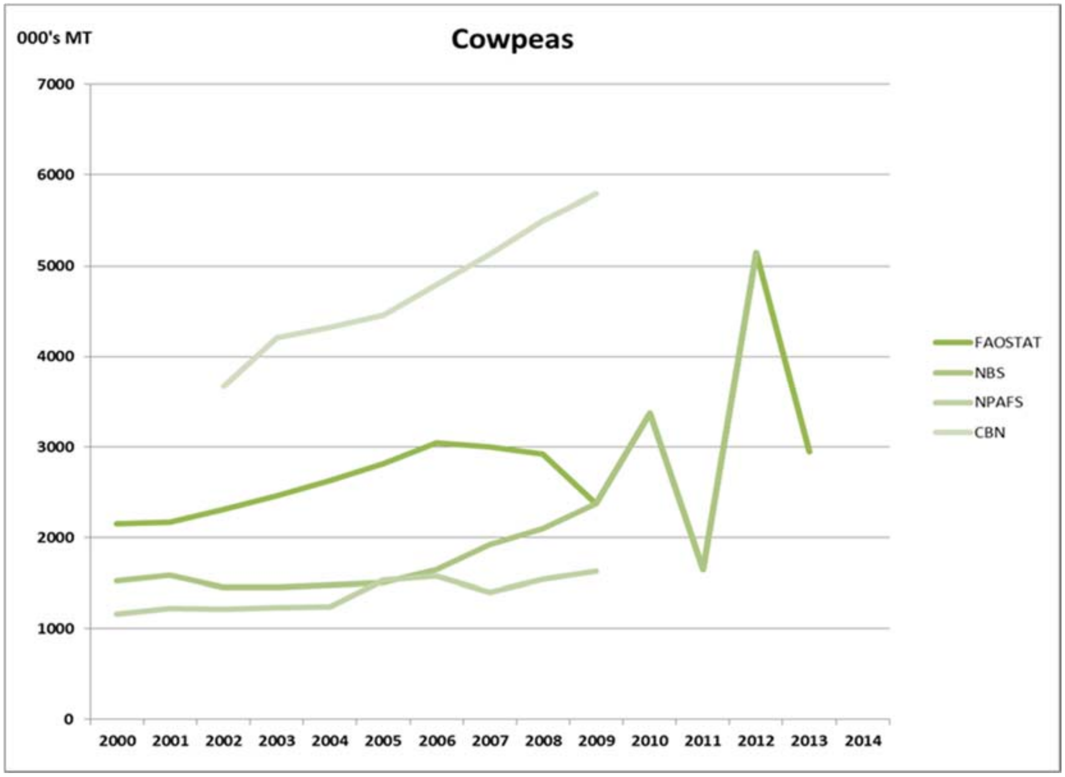

Figure 2-5: Nigerian cowpeas production estimates across sources for the period 2000-13

2.2.5 Statistical rebasing and revisions

The plots for millet and cowpeas production estimates, included respectively in figures 2-3 and 2-5, show that NBS decided to "rebase" its estimates for millet in 2011 and cowpeas in 2012. For millet, this rebasing of estimates resulted in a stark 75% reduction between the 2010 and 2011 estimates, and for cowpeas, the rebasing resulted in a similarly extreme upward adjustment in 2012 to reach an estimate that was three times as large as that for 2011. These are implausibly explained as dramatic changes in actual production, and more likely reflect adjustments in data gathering methodology[20].

Statistical rebasing and subsequent revisions of previous estimates is a common practice among statistical agencies throughout the world, and is commonly done, for example, to correct mistakes, encompass previously non-consulted data, update base periods (if indexed), and utilize updated estimation methods (Carson, Khawaja, and

[20] With regard to use of these statistics in empirical research, the practice of rebasing these statistics and not following up with adjustment of prior estimates essentially makes use of "historical" time series data for these estimates pointless.

Morrison 2004). The USDA National Agricultural Statistics Service (USDA-NASS) statistical revision methodology states that any historical survey data are subject to revision, but only up until a census of agriculture is implemented. A census of agriculture is implemented every 5 years in the U.S., which implies that estimates for each year following a previous census and up until the next census are subject to revision (USDA-NASS 2010). U.S. agricultural statistics may, therefore, be rebased using new information obtained either from the agricultural census or another source, but in addition, all of the applicable estimates would also be revised from the previously reported values to reflect this rebasing.

The method of rebasing according to an objective, comprehensive census, and then subsequent following up with associated revisions for applicable statistics does not appear to have been done by NBS in its rebasing of millet and cowpeas production estimates. Rather, it appears that NBS implemented a survey in 2010-11, which led it to rebase its millet and cowpeas estimates in 2011 and 2012, respectively, such that they were starkly different from those in all preceding years. NBS did not then follow through with supplemental revisions of previous estimates after the rebased estimates were obtained. The failure to revise existing estimates following a rebasing leads to much confusion about the accuracy of any of the existing historical estimates. The notable divergences in USDA-PSD and FAOSTAT estimates for millet and FAOSTAT estimates for cowpeas that follow the respective rebasing year reflect this confusion.

2.3 Description of Data Quality Assessment Methods and Data Used

The preceding examination of summary statistics and visual plots of historical agricultural statistics for Nigeria leads to the conclusion that there is currently widespread uncertainty with regard to the quality of existing agricultural production data. In the next stage of this study, an empirical assessment is undertaken to assess of the quality of these data. The following empirical assessment of the quality of these data has four main components: 1) analysis of cross-source coordination; 2) estimation of the degree to which production and yield measures correlate with NDVI; 3) estimation of how well production measures correspond with prices; and, 4) appraisal of the extent of co-movement between the NDVI and prices. The goal of the assessment of cross-source coordination is to find further evidence of independence across national sources, which would arise mainly through the implementation of surveys. Estimation of the correlation between production estimates and NDVI allows for a comparative analysis of the degree to which sources encompass non-survey information in their estimates, and thus, more realistically reflect inter-year fluctuations in agricultural vegetation. If the production and/or yield estimates do not correlate well with NDVI, then either they or the NDVI data do not reflect conditions on the ground. Agricultural prices are, thus, used as an additional data entity that also plausibly capture on the ground conditions. The discussion below describes the economic theoretical relationship between prices and agricultural production. If agricultural production is high (low) and there is no other adjustment in supply or demand conditions, then prices are low (high). Hence, there is a negative correlation. If NDVI data are not correlated with estimated production, and estimated production data are also not correlated with prices, then the final step in the analysis is to assess the relationship between NDVI and prices. If high correlation is found between NDVI and prices, but not between production and either NDVI or prices, then the production estimates are judged to not reflect local conditions, and thus, be of poor quality. This use of three types of on the ground information (production estimates, NDVI, and prices) is an innovative approach that allows for verification agricultural production estimates in the absence of an agricultural census.

2.3.1 Cross-source coordination analysis method

The first stage of the assessment of data quality is to build upon the observations of the summary statistics and data plots for the national production estimates through calculation of correlation coefficients between national and state level production estimates. Recall from table 2-1 that there is a high degree of cross-source reliance on other sources. With regard to the national sources, NPAFS relies solely on ADP and other state ministry of agriculture agency data for its estimates, while NBS has occasionally relied on ADP data but also implemented its own surveys. In order to assess how well these national sources coordinate with ADPs, estimates directly from three state ADPs (Oyo, Niger, and Kano states) were obtained. These were used to calculate correlation coefficients between the ADP estimates and those reported by the national sources.

International sources rely on national source data, but also commonly other non-survey information (e.g., remote sensing). Correlation coefficients between international and national source estimates, and between national source estimates from different institutions, thus, provide insight into both how well the sources coordinate with each other and the degree to which they rely on independent information.

A high positive correlation coefficient implies that the sources are greatly reliant on each other for information, and also coordinate well. A low positive (or negative) correlation coefficient suggests that the sources are independent of each other, either because they adjust common base estimates using different non-survey information and/or methods, or because they do not trust that the survey information is representative because of poor perceived survey design and/or implementation.

It is expected that the state estimates for NPAFS are relatively more highly correlated with ADP data than those of NBS, because NPAFS explicitly states in the metadata section of its most recent report that it relies solely on ADP and/or other state ministry of agriculture agency data for its state level estimates (NPAFS (2010)). NBS, on the contrary, only relied on ADP data until 2003, at which time it began to implement its own surveys (recall above that it is uncertain whether the NBS data for the period 2007-09 are from ADP surveys, or some other source). By implication, the NBS and NPAFS national level estimates (which are summations of state level estimates) are also expected to not be highly correlated with each other. Based on the common characteristic of reliance on outside information (e.g., remote sensing, rainfall) for adjustment of national source estimates among international sources, it is expected that the estimates of AMIS-FAO, USDA-PSD, and FAOSTAT have broadly high correlation coefficients. Based on the plots in figures 2-2 through 2-5, FAOSTAT appeared to have relatively closer alignment to national sources, and so its estimates are likely more highly correlated with NBS estimates than those of AMIS-FAO or USDA-PSD. There could, however, be low correlations between FAOSTAT and NBS estimates for some crops because the FAOSTAT estimates only converged toward the NBS estimates in the latter part of the 2000-13 period (as observed in figures 2-2 through 2-5).

2.3.2 Relationship between NDVI and agricultural production

Since there has not been an agricultural census conducted in Nigeria since before the 1980's, an alternative method for objective verification of agricultural production estimates using other on the ground information (NDVI and price data) is used in this paper. The method of calculation of correlation between NDVI data and agricultural production estimates is justified based on strong correlations between these variables discovered in the remote sensing literature. Specifically, Tucker et al. (1985) and Prince (1991) identified a strong positive correlation between biomass and satellite measures of vegetation (NDVI and others) in the Sahel region of Sub-Saharan Africa (within which Northern Nigeria resides). Rasmussen (1992) found that NDVI data are positively correlated with vegetation growth specific to agricultural crops. Due to this positive relationship, NDVI data are now commonly used to in reports of national level agricultural production estimates and forecasts (Funk and Budde 2009). On a smaller scale, Singh et al. (2002) showed that the accuracy of ground-based yield estimates that are averaged over space (e.g., those obtained using crop cuttings from farms in different locations) can be improved through the use of NDVI data to make stratification decisions prior to farm survey implementation. Lastly, Chang et al. (2007) established that remote sensing information can be helpful in making or validating planted area estimates for crops with certain characteristics by distinguishing some crop types from both other crops and other non-agricultural vegetation.

There are couple of issues that pertain to the use of NDVI data in an assessment of agricultural production data quality. These issues arise because both agricultural production and NDVI data are estimates over both time and space. NDVI data by nature reflect seasonal variation in vegetation, which fluctuates across months within a crop year. Rasmussen (1992) found that users of NDVI data often have different rules for selection of NDVI data time intervals based on whether they are interested in measuring agricultural yield or total biomass, and the crop of analysis. In the yield case, measures of NDVI over just the growing season, or a segment of it, are often most pertinent (Rasmussen 1992). Additionally, the NDVI data included in an analysis is naturally a function of the area of observation, since NDVI measures for areas that are larger than one pixel are averages of NDVI values across pixels in a given area (Funk and Budde 2009). Bias in an estimate can result if a small observation space is used to represent a larger space if small space does not fully reflect the geophysical and climatic characteristics of the larger space (i.e., information is lost when the information obtained from the small space is aggregated to apply for the large space) (Singh et al. 2002).

In order to address these issues, multiple time intervals and space sizes for NDVI data were included in the subsequent empirical analysis. Four time intervals for NDVI measures were identified from studies in the remote sensing literature. These are:

1. Annual average NDVI value (Ichii, Kawabata, and Yamaguchi 2002);
2. Annual growing season average NDVI value (Rojas 2007);
3. Value associated with the month for the peak NDVI measure (Rasmussen 1992; Hochheim and Barber 1998); and,
4. Value associated with the month with the most NDVI anomalies (Masselli et al. 1992).

There does not appear to have been a remote sensing analysis that explicitly examined the relationship between NDVI and Nigerian agricultural production or yield estimates (either national or local)[21]. All four time interval measures are, thus, consulted and compared. Since the remote sensing studies of Rasmussen (1992) and Masselli et al. (1992) were implemented in the Sahel region, it is expected that annual growing season average NDVI or the NDVI value associated with the month with the most NDVI anomalies may be most highly correlated with estimated production in Northern Nigerian states, especially for the crops primarily grown in that region (e.g., maize, millet, sorghum, and cowpeas).

There were multiple scopes of areas over which NDVI values were averaged. One was associated with the Northern Nigerian region, since a measurement of NDVI across a

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[21] Some readers may be concerned with the inclusion of cassava and yams in the analysis, since these are "underground" crops grown primarily in tropical regions that do not have as much precipitation variation as more temperate areas (Lebot 2009). To the author's knowledge, there has not been much analysis on the relationship between climatic variables (e.g., rainfall or NDVI) and cassava and yam production and yield. Howeler (2001) found, however, that cassava yields were higher if cassava was planted at the beginning of the rainy season relative to other parts of the year. This is suggestive evidence that supports the suspected relationship of higher cassava and yam production in years with overall higher vegetation and so NDVI values.

larger region was assumed to be needed to capture inter-annual fluctuations in agricultural production for crops grown in many states throughout the region. The other scope was smaller and associated with the borders for select states, based on the intuition that state production would be associated with fluctuations in vegetation among farms within its border. The following discussion on the theoretical and empirical relationships between agricultural production and prices helps to further assess these choices of scopes for the empirical analysis.

2.3.3 Production, NDVI, and price relationships

Price data are consulted in addition to NDVI data to measure co-movement with estimated production, because prices are another type of "on the ground" information. Price data have strong theoretical and empirical linkages to agricultural production estimates (as either measured through surveys or by remote sensing). Sahn and Delgado (1989) describe the basic idea of "anticipatory price formation" economic models in agricultural markets, an early version of which was developed by Working (1958), in which current market transactions, and thus prices, are dependent on expectations of future production and demand. In such an anticipatory price model, uncertainty with regard to future supply, due to, for example, variable production or arrival of other supplies (e.g., imports), influences market actor decisions to consume and/or store, with impacts on current market outcomes (including prices) (Working 1958; Goldman 1974). A large (small) expected harvest leads to lower (higher) current and future prices. Prices and estimated supplies are, thus, negatively correlated. The degree of correlation between prices and supplies varies over time, however, as market participants continually update their expectations, and the market adjusts to reflect actions made based on those updates (Working 1958).

In addition to the timing of market operations, the size of the market also matters for determination of relevant supply and demand, and thus prices. In the spatial market model of Ravallion (1986), for example, a market price in a commercial hub is formed from the prices of markets that provide supply to the commercial hub, in addition to other factors (e.g., weather). The prices in a rural market that does not have consistent linkages to a commercial hub (or other non-hub markets) are, thus, determined relatively less by prices in other markets than by local conditions. In such a spatial equilibrium model, the relevant supply of the commercial hub comes from a much more expansive area and number of markets than is the case for a relatively isolated rural market. Growing conditions associated with the larger aggregation area are then relevant for the commercial hub, while growing conditions in only a localized area affect conditions in the isolated rural market.

Recent price formation analyses, such as those by Brown and Kshirsagar (2015) and Baffes, Kshirsagar, and Mitchell (2015), have found that NDVI data help explain price variation of agricultural crops in different contexts in Sub-Saharan Africa. These studies, however, do not provide clear guidance for choice of the relevant area of observation for aggregation of NDVI data into regional measures. Baffes, Kshirsagar, and Mitchell (2015) used two NDVI measures, which were averaged over space and associated with Northern and Southern Tanzanian regions, respectively. The authors do describe some markets in Tanzania as “isolated” and relatively more highly influenced by local conditions such as weather than other markets. The implicit assumption of their framework, however, is that, even for the isolated markets, the relevant NDVI measure is the broad regional measure for either the Northern or Southern zones (Baffes, Kshirsagar, and Mitchell 2015). Similarly, Brown and Kshirsagar (2015) appear to obtain an average NDVI value across space for four area “clusters” in each country, and then use each of these in a set of models and compare results. Although the “optimal” model is reported, the specific area with which the results of the optimal model are associated is not. In light of these differences in methods employed in these studies, both broad (e.g., areas over multiple states) and narrow (e.g., within one state border) area measures are used in the empirical analysis in this paper for comparison.

Sahn and Delgado (1989) argued that the anticipatory price model fits the stylized facts of rural agricultural markets in West Africa based on observations of price fluctuations during the onset of a growing season and in the months that follow and precede harvest. Thus, it is expected that both estimated and actual production for the analyzed markets are negatively correlated with prices. This correlation may not only vary over time, as argued by Working (1958), but also if the incorrect production area is chosen for observation of market participant expectations (as argued in the above described remote sensing literature by Singh et al. 2002).

The empirical method of Working (1958), which includes the estimation of correlation coefficients between prices and estimated supply, is employed here in an expanded form that includes estimation of correlation between estimated production and NDVI, production and prices, and NDVI and prices. The various potential NDVI measure time intervals described above are included as alternative measures for expected production. Spatial market aspects are also accounted for through inclusion of various plausible area measures (e.g., state borders or regions composed of the area of multiple states).

2.3.4 Data used in the empirical analysis

Maize, millet, sorghum, rice, cassava, yams, and cowpeas remain the crops of focus. Three types of data were used: 1) production and yield data (national and state level); 2) NDVI data; and, 3) urban and rural prices. Data for production, yield, and prices are described below. The NDVI data are described in more detail in appendix 2A of this chapter. Figures 2-7 through 2-9, which include maps with associated NDVI measures for select months for the cropland areas of Northern Nigeria, Borno State, and Kano State, are described and displayed below. The cropland area was determined using a cropland mask developed by the African Soil Information Service (AfSIS). This cropland mask separates out urban and heavily wooded areas so that they are not included in the spatial averages for the respective observation region (AfSIS)[22].

2.3.4.1 Production and yield data

National level production data for all sources included in table 2-2 were used except for those of CBN, because it was identified as an outlier in examination of the summary statistics and data plots. Yield data were not consulted at the national level

[22] A description of the methods for construction of the cropland mask can be found at the following AfSIS blog post: http://africasoils.net/2015/06/07/new-cropland-and-rural-settlement-maps-of-africa/. Additionally, the R-code used to create an analogous cropland mask for Tanzania, which has further details of the methods, was published by Dr. Markus Walsh, Senior Research Scientist at AfSIS, and can be found on the following website: https://github.com/mgwalsh/Geosurvey/blob/master/TZ_GS_ensemble.R.

because the inferences from the correlations using national production data were assumed to be applicable for both production and yield[23]. The national level production estimates are annual observations for the period 2000-09.

Both production and yield data were obtained at the state level from state government ADPs, NBS, and NPAFS. Figure 2-6 shows a map of the states from which ADP data were gathered (Oyo, Niger, and Kano states[24]), as well as the other states included in the analysis (Katsina and Borno states). The state level production and yield estimates are annual observations. NBS data are for the period of 2001-10, and NPAFS and ADP data are for 2000-09.

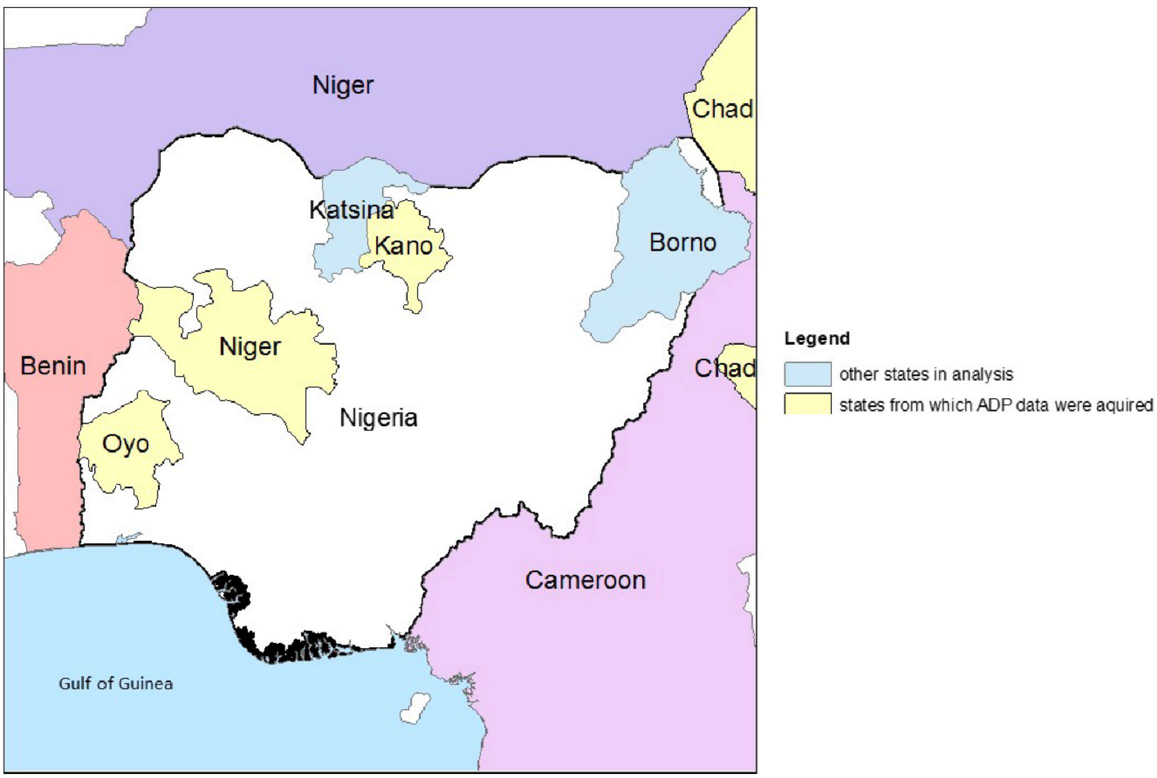

Figure 2-6: Map of states from which ADP data were acquired and other states in the analysis

[23] This assumption appears to be justified based on the state level results.
[24] The ADP in Kano State is named Kano State Agricultural and Rural Development Authority (KNARDA).

2.3.4.2 Price data

All price data were obtained from NBS. These are monthly state level urban and rural prices for Niger, Katsina, Kano, and Borno states. The urban prices are prices aggregated across urban areas in each state. The urban prices are monthly observations for the period 2001-10. The months of September, October, and November were chosen for examination, because they are described as potential harvest months for the various crops included in the analysis in the FEWS-NET "seasonal calendar" for Nigeria. This FEWS-NET seasonal calendar shows that, in normal weather years, most of the crops are harvested in Southern Nigeria by November and in Northern Nigeria by December. The choice of the month at the end of the growing season for comparison with inter-annual production estimates is consistent with the Working (1958) anticipatory price model that presumes that market participants know the magnitude of the harvest at that time and make marketing choices accordingly. The aggregation of market participant choices then achieve a supply and demand equilibrium at the associated seasonal postharvest month price (which may vary across crops and regions).

There are a few issues with these price data. The millet data for all states for 2008 were obviously subject to a transcription error[25]. Also, Borno State data are not available for 2001, and so those price series begin in 2002.

2.3.4.3 NDVI summary statistics and figures

Summary statistics for the NDVI data associated with the cropland area within the national border of Nigeria, the region of Northern Nigeria, and the state borders of Niger, Kano, Katsina, and Borno states are shown below in table 2-3. NDVI values have a range of -1 to 1. An NDVI value of 1 is associated areas with the highest possible "greenness" or vegetation, while NDVI values of -1 correspond with water bodies[26,27]. It is observed

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[25] Observations in local markets led to the conclusion that the millet data were replaced by plantains (the food item in the row below in the spreadsheet) data for 2008 in all spreadsheets.

[26] Note: the NDVI data are scaled during conversion of satellite data to GeoTiff files for use in ArcMap, so a standard scaling factor of 10,000 is needed to obtain the NDVI values. The full area of Southern Nigerian states, urban areas, and heavily wooded areas were not included in order to isolate relevant cropland. See appendix 2A of this chapter for further details on the construction of the NDVI data in table 2-3 and figures 2-7, 2-8, and 2-9.

[27] There is an issue with regard to the potential that the NDVI data are compromised by cloud cover contamination. The data included here, which are vegetation data obtained from the Moderate Resolution

in table 2-3 that the mean values for NDVI over the observation period are higher for the full country than those in Northern Nigeria and Kano, Katsina, and Borno states. Niger State, located in West Central Nigeria, has both a higher mean NDVI value and higher coefficient of variation than the national measures. Of the Northern Nigerian States of Kano, Katsina, and Borno states, Katsina state has the lowest mean while Kano State has the lowest coefficient of variation (CV). Borno State has the largest range of NDVI values, and the highest CV. This implies that cropland vegetation is more variable in Borno State than in the other examined states, the Northern Nigerian region, and the country as a whole.

Table 2-3: Summary statistics for the NDVI measures for Nigeria, Northern Nigeria, and Niger, Kano, Katsina, and Borno states for the period January 2001 to December 2010

	Range (min : max)	Mean	SD	CV
Nigeria	(0.27 : 0.64)	0.46	0.12	0.26
Northern Nigeria	(0.23 : 0.62)	0.41	0.13	0.32
Niger State	(0.24 : 0.68)	0.48	0.15	0.31
Kano State	(0.19 : 0.59)	0.33	0.13	0.39
Katsina State	(0.18 : 0.54)	0.30	0.12	0.40
Borno State	(0.18 : 0.59)	0.33	0.14	0.42

Figures 2-7 through 2-9 below are maps with associated NDVI measures for Northern Nigeria, Borno State, and Kano State, respectively, for select months. The legend for each figure shows that the lighter areas correspond with higher NDVI values, and, thus, higher vegetation. The urban and heavily wooded areas that are excluded by the AfSIS cropland mask are seen in figures 2-7 through 2-9 as those areas that do not change shade from one year to the next and correspond with cities or forest areas shown on other maps. The observed higher NDVI values in the south relative to the north in figure 2-7 is consistent with the south having a relatively more tropical climate, and therefore, having broadly more vegetation.

Imaging Spectroradiometer (MODIS) Aqua satellite (this data product is called MYD13C2), are “cloud-free”, such that if there is cloud interference at the time of observation then that NDVI measure is replaced by a measure consistent with the historical time series.

Figure 2-7 shows the satellite pictures for Northern Nigerian cropland area for June 2002 and June 2003. June 2002 was a month for which the associated NDVI value was more below the average value for June across the years in the observation period than any other monthly observations and their associated average. June 2003 had a NDVI value that was most above the June average relative to other monthly observations and their associated mean. The increased “greenness” observed in Northeast Nigeria (especially in Borno State) in June 2003 relative to June 2002 is particularly noticeable. Based on these observations of fluctuations in vegetation between these years, it would be expected that prices of crops grown in the Northeast (e.g., millet, cowpeas), would be higher priced in 2002 relative to 2003 (assuming these vegetation deviations continued throughout the growing season and there were no substantial changes to demand or quantities from other sources of supply).

Figure 2-8 focuses on the NDVI measures isolated to the border of Borno State, and figure 2-9 does the same for Kano State. These figures provide insights into the relative importance of local conditions between states with different geographical characteristics. Similar to figure 2-7, figures 2-8 and 2-9 includes two images associated with June 2002, a month with the NDVI value that was most below the June average of all June observations, and June 2003, a month with an NDVI value that was most above the June average of all observations for the same period[28]. There is a striking difference between NDVI values from these two months for Borno and Kano states. Figure 2-8 shows that the Borno State “greenness” varied widely between these years, especially for the large belt in the northwest area of Borno State that borders Niger and the area in the east that is south of Lake Chad. This stark difference in vegetation between June 2002 and June 2003 is not nearly as apparent for Kano State, which only has a small amount of recognized increased “greening” in the southwest in 2003 relative to 2002.

[28] For Northern Nigeria, the June 2002 NDVI value was 6.5% below the average for June for the period of 2001-10, and the June 2003 NDVI value was 8.5% above that average. For Borno State, the June 2002 NDVI value was 15.6% below the June full period average, and the June 2003 NDVI value was 36.5% above that average. For Kano State, the June 2002 NDVI value was 10.4% below the June full period average, and the June 2003 NDVI value was 8% above that average.

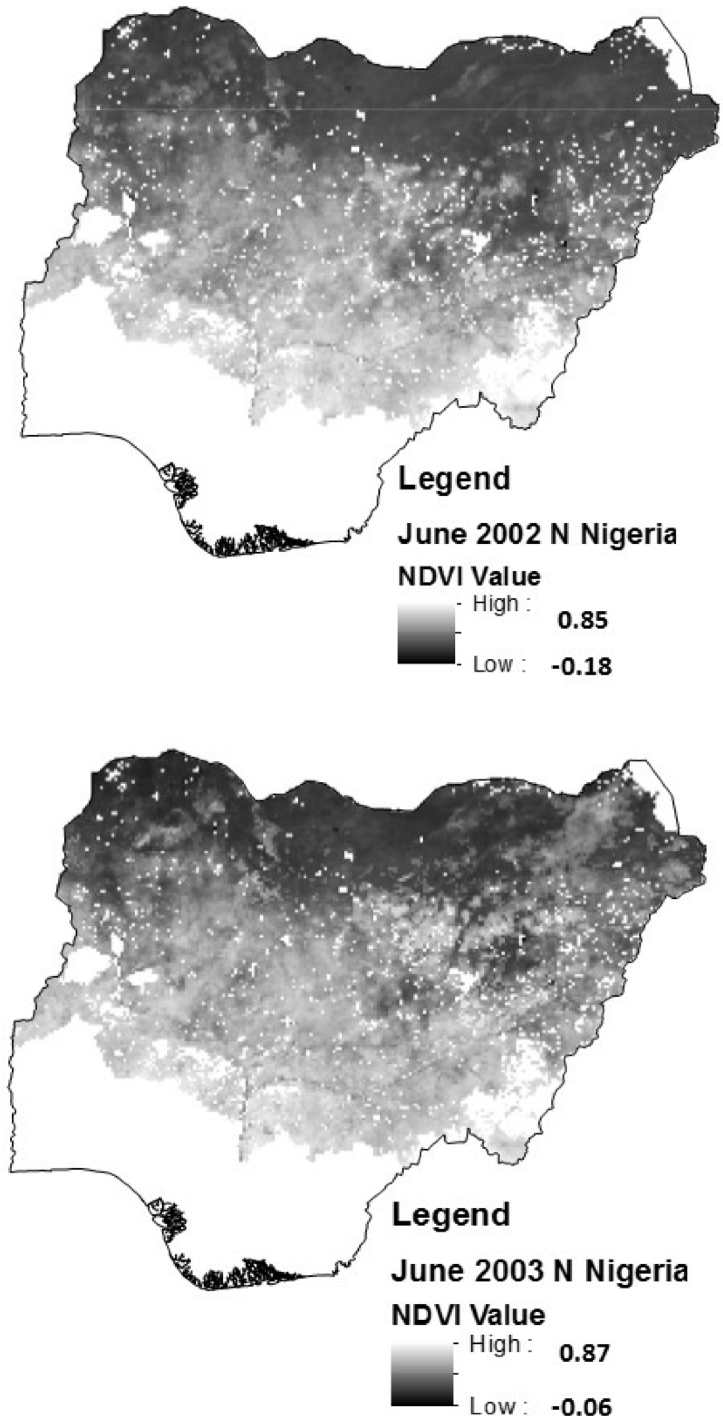
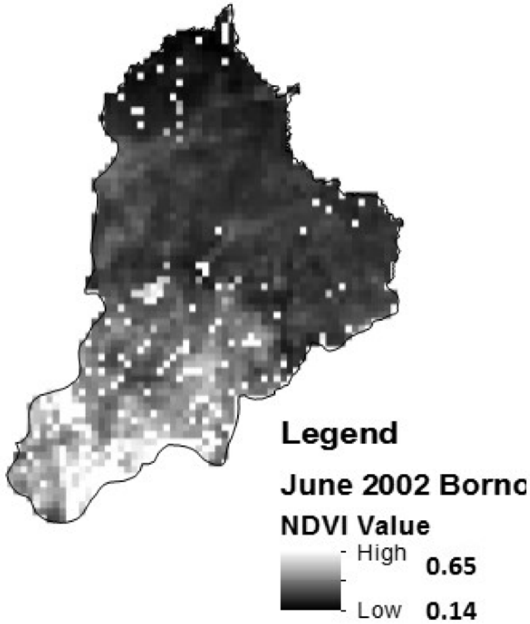


Figure 2-7: Map of Northern Nigeria cropland with associated NDVI measure pixels for June 2002, a low NDVI measure relative to the average NDVI value for June for the observation period (top), and June 2003, a high NDVI measure relative to the same average (bottom)



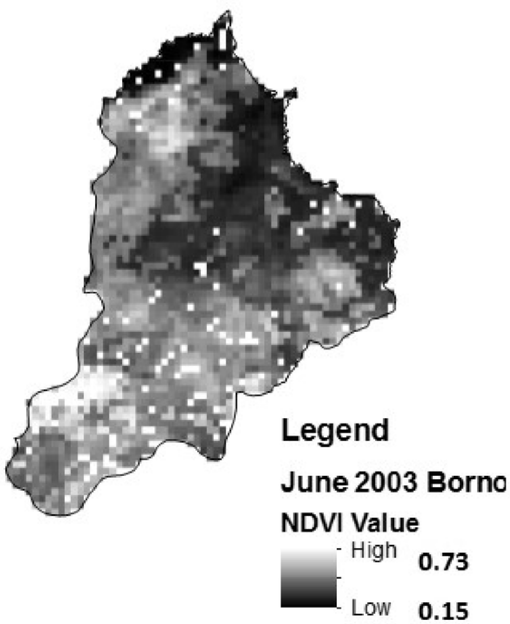


Figure 2-8: Map of Borno State cropland with associated NDVI measure pixels for June 2002, a low NDVI measure relative to the average NDVI value for June for the observation period (top), and June 2003, a high NDVI measure relative to the same average (bottom)

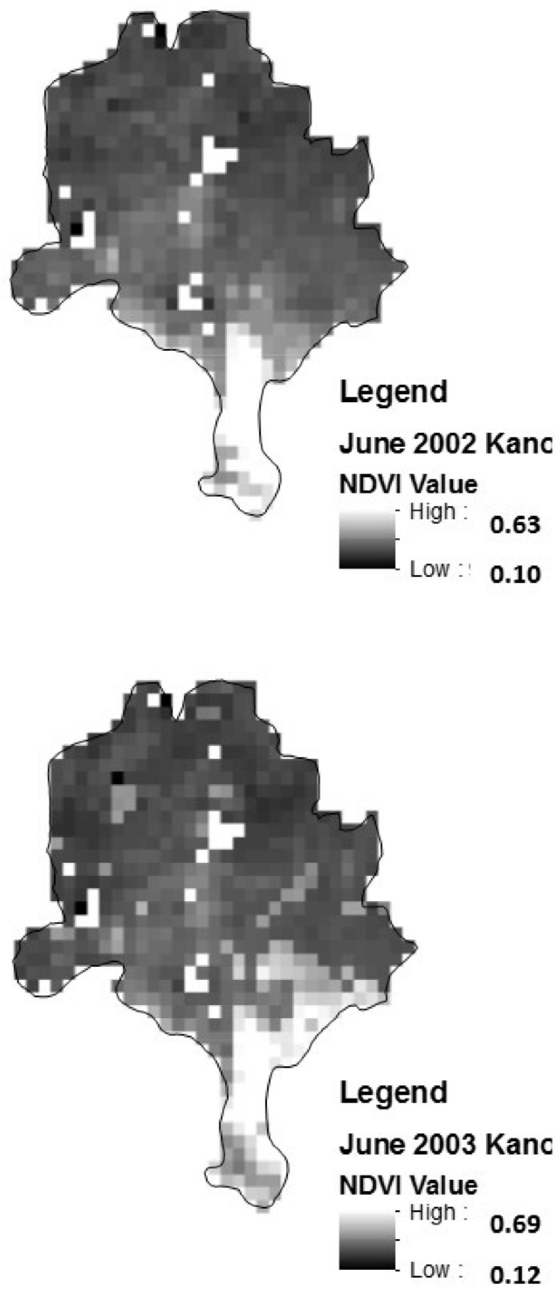


Figure 2-9: Map of Kano State cropland with associated NDVI measure pixels for June 2002, a low NDVI measure relative to the average NDVI value for June for the observation period (top), and June 2003, a high NDVI measure relative to the same average (bottom)

Figures 2-7 through 2-9 allow for further establishment of expectations for correlations between NDVI and prices. Borno State appears to be somewhat unique relative to most areas in Nigeria since it is subject to large inter-year fluctuations in vegetation. This implies that prices in Borno State, especially for those crops grown there (maize, millet, sorghum, and cowpeas) are relatively more likely to be influenced by changes in growing conditions than are those in other states. The empirical analysis that follows will provide insights into whether the data are consistent with these expectations.

2.4 Empirical Results

Results are summarized in the following subsections. Comprehensive results tables for all subsections are included in Appendices 2B-2D associated with this chapter.

2.4.1 Correlations of national production estimates across sources

Table 2-4 below shows the estimated correlation coefficients for national production estimates across sources. The correlation measures in table 2-4 are broadly consistent with expectations based on the data plots in figures 2-2 through 2-5. These correlation coefficients, however, were limited to the period 2000-09 in order to allow for comparison of correlation measures between pairs of sources. For rice, FAOSTAT and USDA-PSD were highly correlated over this period, with an estimated correlation coefficient of 0.99. A correlation coefficient above 0.90 for these two international sources was also found for maize and sorghum. This implies that FAOSTAT and USDA-PSD largely agreed on estimated production for all cereals except millet (with an estimated correlation coefficient of -0.30).

Table 2-4: Correlation coefficients for estimates of Nigerian national crop production for 2000 – 2009 across sources

Rice					
	AMIS-FAO	*USDA-PSD*	*FAOSTAT*	*NBS*	*NPAFS*
AMIS, FAO	1	0.51	0.45	0.64	0.64
PSD		1	0.99	0.48	0.58
FAOSTAT			1	0.39	0.51
NBS				1	0.92
NPAFS					1

Maize					
	AMIS-FAO	*USDA-PSD*	*FAOSTAT*	*NBS*	*NPAFS*
AMIS, FAO	1	0.96	0.96	0.70	0.97
PSD		1	0.95	0.57	0.91
FAOSTAT			1	0.65	0.94
NBS				1	0.72
NPAFS					1

Millet				
	USDA-PSD	*FAOSTAT*	*NBS*	*NPAFS*
PSD	1	-0.30	-0.40	-0.15
FAOSTAT		1	-0.07	-0.40
NBS			1	0.68
NPAFS				1

Sorghum				
	USDA-PSD	*FAOSTAT*	*NBS*	*NPAFS*
PSD	1	0.94	-0.22	-0.21
FAOSTAT		1	-0.17	-0.38
NBS			1	0.47
NPAFS				1

Cassava			
	FAOSTAT	*NBS*	*NPAFS*
FAOSTAT	1	0.70	0.67
NBS		1	0.83
NPAFS			1

Yams			
	FAOSTAT	*NBS*	*NPAFS*
FAOSTAT	1	-0.04	0.50
NBS		1	0.57
NPAFS			1

Cowpeas			
	FAOSTAT	*NBS*	*NPAFS*
FAOSTAT	1	0.23	0.63
NBS		1	0.71
NPAFS			1

It was fairly common across all crops that the international source estimates (AMIS-FAO, USDA-PSD, and FAOSTAT) were more highly correlated with NPAFS than NBS. This finding is somewhat surprising given that NBS is the source to which the FAOSTAT estimates for most crops converged by 2009. There was, thus, apparently a "regime change" with regard to the international source preference for data from Nigerian national sources around this time. This is likely related to the NBS implementation of a survey around 2010, which international sources may have viewed as more plausible to provide valid data than past NBS methods (and those implemented by NPAFS). USDA-PSD also moved toward NBS estimates for sorghum but not until 2009, which leads to a high correlation coefficient between USDA-PSD and FAOSTAT, but a low correlation coefficient (around -0.20) for these sources and NBS for the observation period. USDA-PSD moved toward NBS estimates for millet prior to FAOSTAT, but then diverged again after a few years. FAOSTAT and NBS millet estimates were only similar for years beyond 2009. Thus, USDA-PSD, FAOSTAT, and NBS millet production estimates have broadly low correlation coefficients.

For most crops, NBS and NPAFS estimates are observed to have moved together somewhat well. The correlation coefficients for NBS and NPAFS were above 0.60 for rice (0.92), maize (0.72), millet (0.68), cassava (0.83), and cowpeas (0.71), but below that level for yams (0.57) and sorghum (0.47). This implies that even though there are differences in the levels of the national source production estimates, for most crops, these estimates moved in a similar direction (usually upward) from year-to-year over the observation period.

2.4.2 Correlations of state level production, area, and yield estimates across sources

Recall that the national production estimates from the Nigerian sources are summations of individual state estimates, and that these are gathered from ADPs or state ministries of agriculture (as with NPAFS) or from a combination of these state level sources and independent surveys (as with NBS). It is thus expected that the ADP data are relatively more highly correlated with NPAFS estimates than are the NBS estimates. A low correlation coefficient between NBS and NPAFS implies that the survey implemented by NBS around 2004 led to a movement of NBS estimates away from ADP estimates (and those of NPAFS, conditional on the degree to which their estimates are obtained from ADPs rather than other agencies in the state ministries of agriculture).

These state level cross-source correlations for production and yield estimates were calculated for the period 2000-09 for Oyo, Niger, and Kano states (the states from which ADP data were collected), and are presented below in table 2-5.

Table 2-5: Correlation coefficients for estimates of crop production across state level sources for Oyo, Niger, and Kano states

Oyo State			
	ADP:NBS	ADP:NPAFS	NBS:NPAFS
Maize	0.04	0.42	0.58
Millet	0.54	0.98	0.71
Sorghum	0.35	0.69	0.91
Yams	-0.24	0.66	-0.27
Cassava	0.45	0.55	0.79
Cowpeas	…	…	0.36
Niger State			
	ADP:NBS	ADP:NPAFS	NBS:NPAFS
Maize	0.46	0.97	0.38
Millet	-0.27	0.97	-0.32
Sorghum	0.14	0.67	-0.08
Rice	0.37	0.81	0.49
Yams	0.07	0.92	0.09
Cassava	0.34	0.78	0.13
Cowpeas	-0.07	0.51	0.27
Kano State			
	ADP:NBS	ADP:NPAFS	NBS:NPAFS
Maize	-0.91	0.99	-0.94
Millet	0.42	0.72	0.36
Sorghum	0.52	0.97	0.65
Rice	0.79	0.89	0.91
Cassava	-0.55	0.92	-0.78
Cowpeas	0.01	-0.08	0.64

The results in table 2-5 are broadly consistent with expectations, such that NPAFS estimates are relatively more highly correlated with ADP data across all crops and states (Kano State cowpeas estimates were the only exception). There is some variation in estimated correlation between NPAFS and ADP estimates across states. The correlation coefficients are above 0.80 for most crops for the Niger State ADP and Kano State ADP (KNARDA) and NPAFS estimates, but only above 0.80 for one crop in Oyo State. This implies that NPAFS may have relied on data from other agencies than the ADP in the Oyo State Ministry of Agriculture over this period. The correlation coefficients between NBS and NPAFS estimates are broadly low across all of these states (especially Niger

State), but with some exceptions for individual crops. This suggests that the NBS survey implemented around 2004-06 provided estimates that diverged from the NPAFS estimates, and that the estimates that followed survey implementation also did not move in tandem.

To investigate the issue of whether the difference in production estimates across sources is related to deviations in area or yield estimates (since production is the multiplication of these variables for an area frame), the correlations for area and yield are compared across sources for Niger State (the only state for which the ADP provided independent area and yield estimates). This set of correlation results are shown below in table 2-6. It is observed in table 2-6 that area estimates are relatively more highly correlated across sources compared to yield estimates. Thus, the difference in state level estimates, at least for Niger state, appears to be due primarily to divergent yield estimates. The finding that NPAFS and ADP production estimates are more highly correlated than those for NBS applies for area and yield as well. There is little agreement across NBS and NPAFS for both area and yield estimates (only 2 out of 7 correlation coefficients are above 0.40 for both area and yield). Results below examine whether either NBS or NPAFS yield estimates are correlated with NDVI or prices, and thus, reflect local conditions.

Table 2-6: Correlation coefficients for estimates of crop area and yield across sources for Niger State

Area			
	ADP:NBS	ADP:NPAFS	NBS:NPAFS
Maize	-0.07	0.98	-0.02
Millet	0.59	0.74	0.03
Sorghum	0.62	0.37	0.46
Rice	0.03	0.95	-0.09
Yams	0.68	0.89	0.86
Cassava	0.12	0.39	-0.54
Cowpeas	0.33	0.82	0.05
Yield			
	ADP:NBS	ADP:NPAFS	NBS:NPAFS
Maize	0.52	0.30	0.64
Millet	-0.56	0.81	-0.38
Sorghum	0.05	0.58	-0.12
Rice	-0.60	0.64	-0.36
Yams	-0.29	0.65	0.52
Cassava	-0.14	-0.18	-0.73
Cowpeas	-0.54	0.28	-0.38

2.4.3 Correlations of national production estimates with NDVI

Results for estimation of correlation between these national production estimates and the annual average growing season NDVI value for the entire cropland area of Nigeria are included below in table 2-7. Due to the observations that international and national source estimates for some crops appear to converge around 2007 for some crops, the correlation coefficients were calculated both for the full period 2001-10 and 2007-10. A positive correlation coefficient implies that, consistent with expectations, national production estimates and NDVI values moved together over time, and a negative correlation coefficient means they commonly unexpectedly moved in opposite directions.

The correlation measures for rice production and national growing season NDVI are negative for the full period across sources, and only small and positive for the more recent period for all sources except NBS. The same is true for the maize results for the full period, but the recent period correlation for the maize NBS estimate and national NDVI is a somewhat higher value of 0.46. This value is tied for the highest correlation value of all measures in table 2-7. For the full period, neither NBS nor NPAFS had positive correlation coefficients for any of their crop estimates and NDVI data for the full period. Indeed, only USDA-PSD and FAOSTAT had estimates with positive associated correlation coefficients, and only for 2 of the 7 crops (sorghum and millet).

The finding in table 2-7 that many of the estimates are positive (although still quite low) for the shorter time series of 2007-10 means that the estimates could reflect local conditions better in some periods than others. The data plots in figures 2-2 through 2-5 showed that the international source estimates converged to the national source estimates for most crops beginning in 2006, and by 2009, the international source estimates moved largely in line with the national estimates (even after the apparent rebasing for millet and cowpeas in 2011 and 2012, respectively). This apparent change in view of trustworthiness of national source data by the international sources led to the convergence of estimates, which is a factor decoupled from any changes in agricultural vegetation or production conditions. After the international and national sources moved in line with national estimates, there was more likelihood that the international estimates reflected local conditions as reflected in NDVI data than was the case prior to the adjustment in international and national source cooperation.

The broad picture in table 2-7 is that none of the sources continually encompassed NDVI data into their estimates throughout the full period (or even the more recent period). The finding that these estimates do not well reflect NDVI data, and thus, local conditions, is likely due in part to apparent “regime changes” in the extent to which international sources adjusted their preferences for national source data. The adjustments around 2009 to better reflect NBS data appear to have been made based on reasons other than a recognized better relative reflection of local conditions in those data.

Table 2-7: Correlation coefficients for estimates of Nigerian national crop production and average growing season NDVI for Nigerian cropland for 2001 – 10 and 2007-10

	AMIS-FAO	USDA-PSD	FAOSTAT	NBS	NPAFS
Rice	-0.50 (0.06)	-0.43 (0.19)	-0.40 (0.23)	-0.42 (-0.21)	-0.40 (0.12)
Maize	-0.53 (0.17)	-0.44 (0.18)	-0.42 (0.17)	-0.40 (0.46)	-0.33 (0.13)
Millet	…	0.55 (0.33)	0.23 (0.25)	-0.16 (0.36)	-0.39 (-0.05)
Sorghum	…	0.46 (0.41)	0.38 (0.30)	-0.15 (0.13)	-0.43 (-0.01)
Cassava	…	…	-0.04 (0.26)	-0.03 (0.18)	-0.03 (0.13)
Yams	…	…	-0.15 (0.30)	-0.74 (-0.68)	-0.40 (0.06)
Cowpeas	…	…	-0.18 (0.27)	-0.50 (-0.14)	-0.19 (0.19)

Note: the correlation coefficient for 2001-10 is above that for 2007-10 in parentheses.

2.4.4 Correlations of state level production and yield with NDVI

The degree to which state level production and yield estimates correspond with NDVI data is now assessed. If the national estimates do not reflect local conditions because the state level estimates of which they are composed also do not, then low (or negative) correlation coefficients are also expected between state production estimates and NDVI measures as were found for national estimates.

The state production and yield estimate and NDVI correlation analysis includes Kano, Katsina, Niger, and Borno states, and is expanded to include the four NDVI measures discussed above (annual average NDVI, annual average growing season NDVI, value associated with the month with the highest NDVI measure, and the value associated with the month with the most NDVI anomalies) that are averaged over space by state border. In order to simplify results reporting, the results tables identify the source that had the highest correlation coefficient out of NBS, NPAFS, or ADP, the NDVI measure of the four listed above associated with that highest coefficient, and the estimated correlation coefficient value. Comprehensive results for this subsection are included in Appendix 2B of this chapter.

The estimated correlations for Kano State production and yield and NDVI measures, shown in table 2-8, are broadly quite low. Only the correlation estimates for maize production, cowpea production, and cassava yield are above 0.60. The production correlation estimates are also broadly higher than the associated yield estimates for each crop except sorghum and cassava, a finding which contradicts expectations formed based on findings in the remote sensing literature. While the highest estimated correlations are associated with a few of the included measures of NDVI, the value associated with the peak month of NDVI was most commonly the highest. The NBS yield estimates had the highest correlation estimates (but broadly low in magnitude) for all crops, while the highest correlation estimates for production were associated with estimates from each of the possible sources.

Similar patterns of results to those of Kano State were found for Katsina State, for which the results are also displayed in table 2-8, but with some notable differences. The finding of higher correlation estimates for production and NDVI than yield and NDVI broadly applies for the Katsina State case as it did also for Kano State. Only cowpeas had a higher relative correlation between yield and NDVI than production and NDVI. All of the estimated correlation coefficients are broadly low, with only the estimates for yams production, cowpeas production, and cowpeas yield with NDVI higher than 0.60. It was more common that the Katsina State results for the NPAFS yield estimates were more highly correlated with NDVI than those from Kano State. The value associated with the month with the peak NDVI measure most commonly had the highest correlation estimate across NDVI measures, as was found for Kano State, but the month with the most anomalies (which was one month later than the peak month) was associated with the highest of all of the correlation estimates (for correlation of cowpea yield and NDVI).

Table 2-8: Summarized correlation analysis of production and yield with NDVI for Kano and Katsina states for the period 2000-09

Kano State						
	Production			Yield		
	Source	NDVI measure	Estimated correlation	Source	NDVI measure	Estimated correlation
Maize	NBS	Annual avg.	0.68	NBS	Peak month	-0.17
Rice	NBS	Peak month	0.43	NBS	Peak month	-0.23
Millet	NBS	Peak month	0.47	NBS	Peak month	-0.17
Sorghum	ADP	Peak month	-0.30	NBS	Mo. w/ most anomalies	0.28
Cowpeas	NPAFS	Annual avg.	0.81	NBS	Peak month	0.19
Cassava	NPAFS	Peak month	0.13	NBS	Growing season avg.	0.79
Yams	…	…	…	…	…	…
Katsina State						
	Production			Yield		
	Source	NDVI measure	Estimated correlation	Source	NDVI measure	Estimated correlation
Maize	NBS	Peak month	0.57	NBS	Mo. w/ most anomalies	-0.05
Rice	NBS	Peak month	0.58	NBS	Peak month	0.31
Millet	NBS	Peak month	0.18	NPAFS	Peak month	-0.22
Sorghum	NBS	Peak month	0.33	NPAFS	Peak month	0.30
Cowpeas	NBS	Peak month	0.65	NPAFS	Mo. w/ most anomalies	0.99
Cassava	NPAFS	Peak month	0.14	NPAFS	Peak month	-0.22
Yams	NPAFS	Peak month	0.84	NPAFS	Growing season avg.	-0.90

Note: The relevant sources are NBS, NPAFS, and ADP (for Kano state only). There are 4 possible NDVI measures: annual average NDVI value; growing season average NDVI value; value of month associated with the peak NDVI measure; value of month associated with the month with most NDVI anomalies.

The summarized results for estimation of correspondence between production and yield estimates and NDVI for Niger State are shown in table 2-9, and they vary somewhat from those of both Kano and Katsina states. The correlation estimates, however, are broadly low as was the case with those states. Only the correlation estimates between rice production and cowpea yield and NDVI were above 0.60. Notably, however, all of the correlation estimates for Niger State are positive, which is a distinct difference from the commonly negative Kano and Katsina state estimates. NBS estimates most commonly had the highest relative correlation coefficients for yield relative to the other sources, but NPAFS estimates were associated with the highest for production. A variety of NDVI measures had the highest correlation coefficients, but the value associated with the month with the most NDVI anomalies (which was May) most commonly had the highest correlation coefficients. Cowpeas was the only crop for which the yield had greater relative correlation with NDVI than production.

The summarized results for estimates of co-movement between production and yield estimates and NDVI for Borno State, shown in table 2-9, are distinct from those of the other analyzed states. There was only one estimated correlation coefficient, that associated with cowpea yield, above 0.60 for Borno State, which was the case with Niger State, but lower in number than for Kano and Katsina states. It was more common for Borno State than the other states that the annual average NDVI measure had the highest correlation measure relative to the other NDVI measures. Similar to the results from Katsina State, it was somewhat more common for the production and yield estimates from NPAFS to be associated with the highest correlation coefficients than those from NBS. Borno State was the only state for which there were more crops for which the correlation coefficients for yield and NDVI measures were higher than their associated production estimate correlations. This implies that the results for Borno State relatively better reflect expectations based on findings in the remote sensing literature than those from other states.

Table 2-9: Summarized correlation analysis of production and yield with NDVI for Niger and Borno states for the period 2000-09

Niger State						
	Production			Yield		
	Source	NDVI measure	Estimated correlation	Source	NDVI measure	Estimated correlation
Maize	NPAFS	Mo. w/ most anomalies	0.45	NPAFS	Mo. w/ most anomalies	0.37
Rice	NPAFS	Mo. w/ most anomalies	0.61	NBS	Growing season avg.	0.51
Millet	NBS	Annual avg.	0.46	NBS	Annual avg.	0.36
Sorghum	NBS	Annual avg.	0.09	NBS	Mo. w/ most anomalies	0.09
Cowpeas	NPAFS	Annual avg.	0.53	NBS	Growing season avg.	0.70
Cassava	NPAFS	Mo. w/ most anomalies	0.45	NBS	Mo. w/ most anomalies	0.39
Yams	ADP	Mo. w/ most anomalies	0.54	NBS	Annual avg.	0.01
Borno State						
	Production			Yield		
	Source	NDVI measure	Estimated correlation	Source	NDVI measure	Estimated correlation
Maize	NPAFS	Annual avg.	0.23	NPAFS	Annual avg.	0.20
Rice	NBS	Peak month	0.07	NBS	Annual avg.	0.38
Millet	NBS	Annual avg.	-0.05	NBS	Annual avg.	0.00
Sorghum	NPAFS	Annual avg.	0.20	NPAFS	Annual avg.	0.14
Cowpeas	NPAFS	Annual avg.	0.27	NPAFS	Growing season avg.	0.97
Cassava	NPAFS	Growing season avg.	0.26	NPAFS	Mo. w/ most anomalies	0.30
Yams	…	…	…	…	…	…

Note: The relevant sources are NBS, NPAFS, and ADP (for Niger state only). There are 4 possible NDVI measures: annual average NDVI value; growing season average NDVI value; value of month associated with the peak NDVI measure; value of month associated with the month with most NDVI anomalies.

In summary, the results for the analyzed states showed broadly low correlations between production and yield estimates with NDVI. In only 8 out of 52 total cases was the estimated correlation coefficient above 0.60, a correlation threshold that is often surpassed in the remote sensing literature[29]. It was also observed that for Kano and Niger states, NBS estimates had higher correlation coefficients with NDVI measures than the NPAFS and ADP estimates for most crops. The NPAFS estimates had broadly higher correlation coefficients than the NBS estimates, however, for Katsina and Borno states. These results imply that there is great variation in the degree to which the different source estimates reflect local conditions, but that broadly none of the source estimates reflect fluctuations in inter-year vegetation. In order to verify that the above results show that the production and yield estimates do not reflect local conditions, the estimated correlations between these estimates and prices are assessed next.

2.4.5 Correlations of prices with estimated production

In addition to NDVI data, prices are also a key piece of on the ground information that are reflective of market conditions. Recall that the above discussion on agricultural production and prices described their relationship as one in which the harvest price is dependent on the magnitude of the realized harvest. In years when the harvest is large (small), the prices in the months that lead up to harvest and immediately follow harvest will be lower (higher) than in years of an average sized harvest. A negative correlation between estimated production and harvest period prices is, therefore, expected (as was found in the study by Working (1958)).

Unfortunately the relatively short series of the rural prices do not allow for direct comparison with the results associated with the urban price series, which include observations for the full period of 2001-2010. Thus, emphasis in the discussion of results for both the correlation between production estimates and prices and NDVI and prices (in the next subsection) is placed on the broad measures across both types of prices (urban and rural) rather than differences between the relative correlation magnitudes associated with urban versus rural prices.

To investigate whether the expected negative relationship between estimated production and harvest period prices is consistent with the data, the correlation between

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[29] Rasmussen (1992), for example, estimated a correlation of 0.89 between millet yield in a province of Burkina Faso and the relevant value associated with the peak month of NDVI.

these statistics was calculated. These were calculated across all sources for which there are data, which are: NBS, NPAFS, and ADP for Kano and Niger states; and, NBS and NPAFS for Katsina and Borno states. The annual production estimate series correlation was calculated using three potential harvest months: September, October, and November. In order to summarize results, the estimated correlation coefficients that have the highest absolute value magnitudes out of all source and month combinations are those that are reported. These summarized results are included in tables 2-10 and 2-11 below, and comprehensive results can be found in Appendix 2C of this chapter.

The summarized results for the analysis of correlation between estimated production and harvest period prices in Kano State are shown below in table 2-10. The results show that there are only a relatively few combinations in which the estimated correlation coefficient has the expected negative sign. These are: maize and cowpeas for urban prices; and, millet, sorghum, cowpeas, and cassava for rural prices. These are only 6 cases out of the possible 14 combinations. Those estimated correlation coefficients that do have the negative sign have broadly low relative absolute value magnitudes, such that only the combinations of urban prices of maize and cowpeas, and rural prices of cassava and production estimates have associated correlation estimate with absolute values above 0.40. For both urban and rural prices, the month that corresponded with the estimated correlation coefficient with the highest absolute value magnitude was September for both urban and rural prices. These results broadly imply that the Kano State production estimates do not have the expected negative relationship with harvest period prices in most cases.

Table 2-10: Summarized correlation analysis results of urban and rural Kano and Katsina state prices with production estimates for these states, for the period 2001-10 for urban prices and 2007-10 for rural prices

Kano State						
	Urban prices			Rural prices		
	Source	Price month	Estimated correlation	Source	Price month	Estimated correlation
Maize	NBS	November	-0.48	NBS	September	0.07
Millet	NBS	September	0.13	ADP	September	-0.12
Sorghum	NPAFS	October	0.28	NPAFS	September	-0.11
Imported rice	NPAFS	September	0.73	ADP	September	0.60
Local rice	NPAFS	September	0.76	NBS	November	0.73
Cowpeas	NBS	September	-0.50	NPAFS	October	-0.03
Cassava	NPAFS	November	0.54	NPAFS	October	-0.50
Yams	…	…	…	…	…	…
Katsina State						
	Urban prices			Rural prices		
	Source	Price month	Estimated correlation	Source	Price month	Estimated correlation
Maize	NBS	November	0.60	NBS	September	0.26
Millet	NBS	November	0.53	NBS	November	0.12
Sorghum	NBS	October	0.56	NBS	September	0.15
Imported rice	NBS	September	0.15	NPAFS	October	-0.10
Local rice	NBS	October	0.07	NBS	November	-0.25
Cowpeas	NBS	November	0.45	NBS	September	0.15
Cassava	NPAFS	September	0.83	NPAFS	October	0.81
Yams	…	…	…	…	…	…

Note: The possible months for prices are September, October, and November.

Table 2-10 also shows the analogous summarized results for the analysis of correlation between production estimates and prices for Katsina State. There were only 2 crop and price combinations out of 14 estimates that had the expected negative relationship (local and imported rice and rural prices), which is even fewer than was the case for Kano State. Those that do have the expected negative sign have very low absolute value magnitudes, and neither is above 0.30. These results imply that the production estimates for Katsina State also do not correspond with prices in a manner consistent with expectations.

The summarized results for the correlation analysis between estimated production and harvest period prices in Niger State are displayed below in table 2-11. The expected negative correlation between estimated production and prices was much more common for Niger State than was the case for Kano and Katsina states. Out of the 16 possible price and crop combinations, 10 had the expected negative signs. Those estimates that had the expected negative signs also had somewhat high absolute value magnitudes. Seven of the 10 combinations with the expected negative signs had absolute value magnitudes of above 0.50. The harvest month price that was most commonly associated with the estimated correlation coefficient with the highest absolute value magnitude was November, which is later than those for Kano and Katsina states.

Table 2-11 also includes the summarized results that estimate the correlation between estimated production and urban and rural prices for Borno State. The results for Borno State are more similar to those of Kano and Katsina states than those of Niger State such that there were relatively few price and crop combinations that had a negative estimated correlation coefficient. Out of the 14 possible crop and price combinations, only 5 had the expected negative sign. Negative signs were found for: millet and cassava for urban prices; and, maize, local rice, and cassava for rural prices. October and September were the months that were associated with the estimated coefficients with the highest absolute value magnitudes.

Table 2-11: Summarized correlation analysis of urban and rural Niger and Borno state prices with production estimates for these states, for the period 2001-10 for urban prices and 2007-10 for rural prices

Niger State						
	Urban prices			Rural prices		
	Source	Price month	Estimated correlation	Source	Price month	Estimated correlation
Maize	NBS	November	0.28	NBS	November	0.30
Millet	NBS	November	-0.50	NBS	November	-0.70
Sorghum	NBS	November	-0.29	NBS	November	-0.42
Imported rice	ADP	September	0.65	NBS	October	-0.57
Local rice	NBS	November	0.62	NBS	September	-0.67
Cowpeas	NPAFS	November	-0.50	NBS	November	-0.53
Cassava	ADP	September	0.20	ADP	November	0.33
Yams	NBS	October	-0.13	ADP	October	-0.80
Borno State						
	Urban prices			Rural prices		
	Source	Price month	Estimated correlation	Source	Price month	Estimated correlation
Maize	NBS	October	0.45	NBS	September	-0.15
Millet	NPAFS	November	-0.48	NBS	October	0.23
Sorghum	NBS	September	0.47	NBS	September	0.03
Imported rice	NPAFS	October	0.62	NBS	October	0.54
Local rice	NPAFS	September	0.59	NBS	September	-0.12
Cowpeas	NBS	October	0.14	NPAFS	November	0.50
Cassava	NPAFS	October	-0.73	NPAFS	September	-0.51
Yams	…	…	…	…	…	…

Note: The possible months for prices are September, October, and November.

To summarize, the results in tables 2-10 and 2-11 broadly diverged from the expectations that estimated production and prices have a negative relationship. These results imply that either the production estimates or the prices do not well reflect local conditions. Those in Niger State were somewhat more encouraging, although the comprehensive results in Appendix 2C of this chapter show that the expected results were only commonly found for the NBS production estimates and did not apply for production estimates from the other sources. In the last section, it was found that production estimates do not correlate as expected with NDVI data, and in this section it was established that they broadly do not do so either with prices. The last assessment to make is to investigate the relationship between NDVI and prices. If the relationship is stronger than was found for the prices and production estimates, then it is viewed as evidence that the production estimates do not well reflect on the ground conditions.

2.4.6 Correlations of prices with NDVI

The analysis of correlation of urban and rural state prices with the various NDVI measures maintains the expectation of a negative relationship between these variables, as was the case between prices and agricultural production in the last subsection, since NDVI data are a plausible proxy for expected production. The correlation between both urban and rural harvest period prices and the NDVI measures were summarized as they were in the other subsections such that they only report the best estimates from the comprehensive set of combinations.

The sets of reported estimates for each crop vary based on the potential harvest month price (September, October, or November) and the NDVI measures, which are the same as for the section that examined the relationship between NDVI data and production estimates. Included in the summarized results for each crop, therefore, is the month of the price and NDVI measure associated with estimated correlation coefficient that has the highest absolute value, as well as the estimated correlation value. One difference from the production and yield and NDVI correlation estimates reported in tables 2-8 and 2-9, and the NDVI and price results below is the inclusion of two possible “scopes” of NDVI measures. These scopes pertain to the area over which the NDVI values were averaged, and are either Northern Nigeria or the individual state borders. These two scopes were included to capture the differences in market structure across the states, such that some are more interconnected with markets over a wider area range, and are, hence, influenced by prices over that wider range, than others. The summarized results for the correlations between urban and rural prices and the NDVI measures are in tables 2-12 through 2-15 below, and the comprehensive results are included in Appendix 2D of this chapter.

The results for Kano State, shown in table 2-12, are broadly more consistent with expectations than was the case with the production and yield and NDVI data correlations. They all have the expected negative sign. The magnitudes of the correlation estimates are also broadly high relative to those of the correlations of production with NDVI and prices with production. There are only 3 of the 16 crop price and NDVI measure combinations that had absolute value correlation measures that were less than 0.50. It was commonly the case that the price month associated with the models with best performing measures was later in the crop season for rural prices than urban prices. With regard to the various NDVI measures, the growing season average NDVI value was most commonly associated with the highest absolute value magnitude correlation coefficient for urban prices, but the value associated with the month of peak NDVI also performed well for rural prices. Notably, for every crop, the NDVI scope that the highest absolute value magnitude correlation coefficients was that for Northern Nigeria. This implies that growing conditions throughout Northern Nigeria are relatively more informative for both urban and rural prices in Kano State than are growing conditions only within the state.

Table 2-12: Summarized correlation analysis of Kano State urban and rural prices with NDVI for the period 2001-10 for urban prices and 2007-10 for rural prices

Kano State						
	Urban prices			Rural prices		
	Price month	NDVI measure (scope)	Estimated correlation	Price month	NDVI measure (scope)	Estimated correlation
Maize	September	Growing season avg. (north)	-0.75	November	Peak month (north)	-0.99
Local rice	September	Growing season avg. (north)	-0.42	November	Peak month (north)	-0.97
Imported rice	September	Growing season avg. (north)	-0.35	November	Mo. w/ most anomalies (north)	-0.96
Millet	October	Growing season avg. (north)	-0.41	November	Growing season avg. (north)	-0.98
Sorghum	September	Peak month (north)	-0.58	November	Peak month (north)	-0.98
Cowpeas	November	Mo. w/ most anomalies (north)	-0.58	September	Growing season avg. (north)	-0.96
Cassava	November	Growing season avg. (north)	-0.57	November	Mo. w/ most anomalies (north)	-0.98
Yams	September	Growing season avg. (north)	-0.55	October	Mo. w/ most anomalies (north)	-0.97

Note: The possible months for prices are September, October, and November. The "scopes" of NDVI measures are either Northern Nigeria (north) or the state border (state). There are 4 possible NDVI measures: annual average NDVI value; growing season average NDVI value; value of month associated with the peak NDVI measure; and, value of month associated with the month with most NDVI anomalies.

The Katsina State results for estimation of correlation between prices and NDVI, displayed in table 2-13, reflect well the patterns observed in the Kano State results in most regards. All of the correlation coefficients in table 2-13 have the expected negative signs. The magnitudes of the correlation estimates are also quite high relative to the correlation estimates between NDVI and production and between prices and production, as was the case with Kano State. There were again only 3 of the 16 crop price and NDVI measure combination correlation estimates with an absolute value magnitude below 0.50. It is also the case for the Katsina State results that the month of the price associated with the highest absolute value magnitude correlation coefficients are broadly later in the cropping season for the rural prices than urban prices for most crops (cassava the only exception). There was more homogeneity across NDVI measures associated with the reported correlation coefficients for Katsina State than Kano State. All of the lowest urban price correlation coefficients were associated with the annual average growing season value. The same was found for the rural prices, but the value associated with the month of peak NDVI was also common. The scope of NDVI measures with the highest associated correlation estimates was Northern Nigeria rather than the Katsina State border across all examined cases.

Table 2-13: Summarized correlation analysis of Katsina State urban and rural prices with NDVI for the period 2001-10 for urban prices and 2007-10 for rural prices

Katsina State						
	Urban prices			Rural prices		
	Price month	NDVI measure (scope)	Estimated correlation	Price month	NDVI measure (scope)	Estimated correlation
Maize	September	Growing season avg. (north)	-0.64	October	Peak month (north)	-1.00
Local rice	November	Growing season avg. (north)	-0.45	October	Growing season avg. (north)	-0.94
Imported rice	September	Growing season avg. (north)	-0.47	November	Peak month (north)	-0.97
Millet	September	Growing season avg. (north)	-0.70	October	Growing season avg. (north)	-0.95
Sorghum	September	Growing season avg. (north)	-0.61	October	Peak month (north)	-0.96
Cowpeas	September	Growing season avg. (north)	-0.71	November	Growing season avg. (north)	-0.99
Cassava	November	Growing season avg. (north)	-0.54	September	Peak month (north)	-0.79
Yams	October	Growing season avg. (north)	-0.42	October	Peak month (north)	-0.99

Note: The possible months for prices are September, October, and November. The “scopes” of NDVI measures are either Northern Nigeria (north) or the state border (state). There are 4 possible NDVI measures: annual average NDVI value; growing season average NDVI value; value of month associated with the peak NDVI measure; and, value of month associated with the month with most NDVI anomalies.

The summarized results for correlation estimates of Niger State urban and rural prices with NDVI data are shown in table 2-14. These results are broadly consistent with those for Kano and Katsina states, with only a couple of subtle differences. Similar patterns apply as with the other states such that all the correlation estimates had the expected negative sign. The magnitudes for the correlation estimates are broadly high relative to the correlation estimates for the NDVI measures and production and prices and production. The correlation estimates for Niger State are, however, somewhat lower than those for Kano and Katsina states. Two correlation estimates associated with crop price and NDVI measure combinations had absolute value magnitudes of less than 0.40, while there was only one such estimate for Kano State (for urban imported rice) and none for Katsina State. With regard to the various NDVI measures, the results are similar to those of Katsina State such that the correlation measures with the highest absolute value magnitudes were those associated with the growing season average NDVI and the value associated with the peak month NDVI. The finding that the relative absolute value of the correlation coefficients were higher for the Northern Nigeria scope than that associated with the state border applies for Niger State, as was found for Kano and Katsina states.

The summarized correlation estimate results for Borno State urban and rural prices and NDVI correlation are included in table 2-15 below. The Borno State results broadly reflect the results of the other states, but with a few key differences. Each of the estimated correlation coefficients have the expected negative sign, as was the case with the other states. The absolute value magnitudes of the estimated coefficients are also broadly high relative to the correlations between production and NDVI and prices and production. Indeed, the absolute value magnitudes for the correlation estimates for Borno State prices and the NDVI measures were the highest of all examined states, and there was only one crop price and NDVI measure combination with a correlation estimate below 0.50 (for urban prices and cassava). These results suggest that Borno State prices in general are broadly more influenced by fluctuations in vegetation than those of the other analyzed states. The other main difference between the Borno State results and those of other states is that Borno State was the only examined state for which the correlation coefficient with the highest absolute value magnitude for rural prices were associated with the scope of NDVI determined by the state border rather than Northern Nigeria (while it was Northern Nigeria for the urban prices). This suggests that local growing conditions are of broadly greater importance for determination of Borno State rural prices than those of the other analyzed states. These findings are consistent with Borno State having relatively higher NDVI variation than the other states (as observed in table 2-3).

Table 2-14: Summarized correlation analysis of Niger State urban and rural prices with NDVI for the period 2001-10 for urban prices and 2007-10 for rural prices

Niger State						
	Urban prices			Rural prices		
	Price month	NDVI measure (scope)	Estimated correlation	Price month	NDVI measure (scope)	Estimated correlation
Maize	September	Peak month (north)	-0.34	September	Peak month (north)	-0.99
Local rice	October	Growing season avg. (north)	-0.58	October	Peak month (north)	-0.98
Imported rice	September	Growing season avg. (north)	-0.55	November	Growing season avg. (north)	-0.99
Millet	October	Peak month (north)	-0.38	November	Growing season avg. (north)	-0.93
Sorghum	November	Growing season avg. (north)	-0.63	November	Growing season avg. (north)	-0.84
Cowpeas	October	Growing season avg. (north)	-0.65	October	Growing season avg. (north)	-0.98
Cassava	November	Growing season avg. (north)	-0.59	November	Peak month (north)	-0.94
Yams	November	Peak month (north)	-0.51	September	Growing season avg. (north)	-0.99

Note: The possible months for prices are September, October, and November. The "scopes" of NDVI measures are either Northern Nigeria (north) or the state border (state). There are 4 possible NDVI measures: annual average NDVI value; growing season average NDVI value; value of month associated with the peak NDVI measure; and, value of month associated with the month with most NDVI anomalies.

Table 2-15: Summarized correlation analysis results of Borno State urban and rural prices with NDVI values for the period 2001-10 for urban prices and 2007-10 for rural prices

Borno State						
	Urban prices			Rural prices		
	Price month	NDVI measure (scope)	Estimated correlation	Price month	NDVI measure (scope)	Estimated correlation
Maize	September	Peak month (north)	-0.68	November	Mo. w/ most anomalies (state)	-0.93
Local rice	September	Growing season avg. (north)	-0.83	November	Mo. w/ most anomalies (state)	-0.96
Imported rice	September	Growing season avg. (north)	-0.58	November	Mo. w/ most anomalies (state)	-0.85
Millet	October	Peak month (north)	-0.59	October	Growing season avg. (state)	-0.85
Sorghum	November	Growing season avg. (north)	-0.70	November	Growing season avg. (state)	-0.88
Cowpeas	November	Growing season avg. (north)	-0.68	September	Growing season avg. (state)	-0.88
Cassava	November	Growing season avg. (north)	-0.46	September	Mo. w/ most anomalies (state)	-0.89
Yams	September	Growing season avg. (north)	-0.62	October	Peak month (state)	-0.90

Note: The possible months for prices are September, October, and November. The "scopes" of NDVI measures are either Northern Nigeria (north) or the state border (state). There are 4 possible NDVI measures: annual average NDVI value; growing season average NDVI value; value of month associated with the peak NDVI measure; and, value of month associated with the month with most NDVI anomalies.

In summary, the results for the correlation estimates of urban and rural prices and the NDVI in tables 2-12 through 2-15 were much more consistent with expectations based on theory and previous empirical observations than was the case for the production and yield estimates and NDVI. The correlation estimates that performed best for each crop all had the expected negative sign, and the magnitudes of the correlation estimates were broadly higher than those for NDVI and production and prices and production. For Kano, Katsina, and Niger state urban and rural prices, and Borno State urban prices, the scope of NDVI that led to the highest absolute magnitude correlation coefficients was that associated with Northern Nigeria. The state border scope, however, led to the highest absolute value correlation coefficients for Borno State rural prices. These results imply that prices of the analyzed crops in the examined states, are broadly well informed by fluctuations in vegetation, but the degree to which these prices reflect local conditions varies across states.

The finding that the correlation measures for prices and NDVI measures broadly reflect expectations based on theory and empirical observations, while those of production and NDVI and production and prices do not, leads to the conclusion that very little production data in Nigeria capture well inter-annual changes in local conditions. This calls into question the suitability of the production and yield data for use in empirical studies, and raises the question of how remote sensing data such as NDVI can be utilized to improve the quality and accuracy of production and yield estimates at the state and national levels in a cost-effective manner in the future.

2.5 Concluding Remarks

The presence of multiple state and national level sources that provide estimates of agricultural production in Nigeria leads users of these data to make choices across sources in an unclear environment. Ideally, an agricultural census could be conducted in order to verify existing estimates, as is done in the U.S. every five years (USDA-NASS 2010), and provide guidance for identification of the best quality estimates. Such a census, however, has not been implemented in Nigeria since before the 1980's (Onyeri 2011). Current agricultural statistics in Nigeria, therefore, appear to broadly be in a problematic state. The data descriptions and empirical analysis in this study shed light not only on the current poor quality of the vast majority of these data, but also provides insights into a possible path to improve data quality through a mix of established best practices and new technologies.

The study reviewed existing metadata documentation and associated data in order to identify a clearer story of how state and national level agricultural data were constructed and how they have evolved over time. The metadata documentation and data plots showed that the degree to which sources have relied on the data of other sources has varied over time, and the periods of divergence are often associated with the timing of survey implementation. This leads to the conclusion that the estimates, which differ widely from those of previous years, reflect a new data gathering method rather than changes in local conditions (e.g., weather). The empirical analysis in this study was designed to discern whether the data are consistent with these observations. The estimated relationships between production estimates, NDVI, and prices also provide insight into the degree to which production and growing conditions information explains price variation relative to other factors (e.g, external market prices), which is the subject of Chapter 4.

The empirical analysis led to four main discoveries. The first, obtained through visual plots and cross-source correlations, is that, although the sources of data appear to coordinate with each other, large divergences in estimates across sources at times are apparent in years for which there is record of actual survey implementation in the metadata documentation. Specifically, for the cases of millet and cowpeas, implementation of the 2010-11 NBS National Agricultural Sample Survey led to complete rebasing of estimates that were far from those of years previous (without revisions of prior estimates, as is standard practice of statistical agencies in other countries (Carson, Khawaja, and Morrison 2004)). While international sources have relied on national sources for information over time, the degree to which they do so has varied. Additionally, the most recent national source estimates are only available through 2012 (which may actually be forecasts based on 2011 estimates), so the production estimates by international sources for the current crop year 2015-16 must be forecasts based on national source data that are nearly five years old and have not been verified for accuracy.

Secondly, the national and state level production estimates, as they currently exist, do not correlate well with NDVI measures, which have a broad and clearly established positive correlation with agricultural vegetation in the remote sensing literature (e.g., Rasmussen 1992). The national estimates likely do not correlate well with NDVI information at least in part because, as noted above, they have been adjusted based on the implementation of new survey methods rather than due to changes in conditions on the ground. They may additionally not correlate well with NDVI because it is not clear in the metadata documentation how and if weather information is consulted in making agricultural production estimates for non-survey years. The state level production estimates are somewhat more highly correlated with NDVI than the national production estimates. The degree to which these correspond with NDVI is broadly low, however, across all four examined states and crops.

Thirdly, the degree to which production estimates correspond with prices is also broadly low. In three of the four examined states, with Niger State as a somewhat exceptional case, there were only a few of the possible crop and price combinations for which the correlation estimates for production and prices had the expected negative sign. Additionally, for the few combinations that had the expected negative sign, the absolute value magnitudes of the coefficient estimates were broadly low. In only a very few cases were the absolute value magnitudes of the correlation estimates above 0.50. While the production estimate and price relationships were somewhat better for Niger State, even in this case the expected negative sign was only regularly found for production estimates from NBS and not the other sources (as seen in Appendix 2C of this chapter). These results imply that the production estimates do not well reflect prices, which further casts doubt on the degree to which the production estimates reflect local conditions.

The last finding is that prices do broadly appear to correspond well with NDVI. Unlike the correlation measures between production estimates and prices, the correlation estimates between the NDVI and prices only rarely did not have the expected negative sign. The finding of high absolute value magnitudes for the estimated correlation coefficients for prices and the NDVI measures broadly applied for all states and crops. The absolute value magnitudes of the correlation estimates that were the highest among the possible source and NDVI measure combinations (reported in tables 2-12 through 2-15) were only rarely below 0.50.

In summary, there were three sequential findings: broadly poor correlation between production and yield estimates and NDVI; generally low correlation between production estimates and prices; but, commonly strong correlation between prices and NDVI. Of the four examined states, only for the results for Niger State did the estimates for each set of correlations align somewhat consistently with expectations for each set. These results broadly suggest that production estimates for most of the examined states do not correspond well with two independent on the ground measures of local growing season conditions (NDVI and prices), while those independent measures do correspond well with each other. This discrepancy means that most production estimates in Nigeria do not reflect local conditions.

These results also suggest that NDVI and other remote sensing information can be used for verification of existing data, as was implemented for the case of Nigeria in this study. Remote sensing information would plausibly also be helpful for development of an achievable strategy for improvement of Nigerian production data in the future. While these NDVI data are highly correlated with prices, and thus appear to be informative for current conditions (as they are currently used by FEWS-NET), there still remains much to do to establish an accurate baseline for both state and national level agricultural production estimates.

Any strategy to improve these data must take into consideration the current poor funding environment for all current data gathering efforts (NAERLS and NPAFS 2012; AMIS 2014). Since remote sensing data like the NDVI incorporated here are currently freely available as provided by the U.S. National Aeronautics and Space Administration (NASA), these data are plausibly a key component of an improved but cost minimizing strategy for gathering improved agricultural production data in Nigeria.

Some financial resources, however, will need to be invested if there is going to be any improvement upon the status quo. Intra-crop year farm surveys cost money, but they are the gold standard for obtaining accurate area and yield estimates (Allen 2007). The cost of implemented surveys may be reduced, however, through strategic sampling methods that utilize satellite imagery and other remote sensing technology to distinguish relevant agricultural sampling area frames from non-agricultural land (Singh et al. 2002).

Additionally, “crowd sourcing” methods may be utilized in order to obtain more accurate crop area estimates. For example, the African Soil Information Service (AfSIS) has an internet-based application “Geosurvey” that is a crowd source based data gathering tool, in which individual users upload geospatial information for parcels of land such that each data entry includes information on the location and type of land (e.g., cultivated, non-cultivated farmland, or non-farmland). Verification and/or supplementation of the crowd sourced data could occur using other technologies as well.

For example, the Premise Data Company has developed innovative methods that use mobile phones to obtain data observations across space and time, and records individual data entries in a manner that automatically indexes those observations tailored to user needs.

A thorough empirical analysis is apparently needed to estimate the relative cost-efficacy of various data gathering systems that encompass different combinations of the above mentioned methods and technologies (i.e., surveys, remote sensing, and/or crowd-sourced information) and are able to achieve some data quality standards. Political will is needed in order to both support such a study and follow through with establishment and implementation of a new, improved data gathering regime that would be recommended from the study. Until the agricultural data gathering systems are improved, however, Nigerian policymakers at all levels will continue to make agricultural policy decisions in the dark.

CHAPTER 3. PRICE TRANSMISSION IN NIGERIAN FOOD SECURITY CROP MARKETS

3.1 Introduction

Research attention on the effects of world food price increases on prices in Sub-Saharan African (SSA) country markets has increased markedly since the "food crisis" of 2007-08. Recent food price transmission studies (e.g., Minot 2011; Abbott and Borot de Battisti 2011; and, Baltzer 2015) expanded on earlier analyses by Baffes and Gardner (2003) and Conforti (2004), which broadly found incomplete price transmission from world to SSA country markets, but with variation across countries and crops. In light of these discoveries, Baffes, Kshirsagar, and Mitchell (2015) sought to discern whether regional (neighboring country) prices or local conditions (e.g., weather) are relatively more important than world prices in local price formation.

In this study, we implement a comprehensive price transmission analysis that measures food price transmission to Nigerian markets of different "scopes": world to commercial hubs and other urban markets, neighbor country markets to commercial hubs and other urban markets, commercial hubs to other urban markets, and urban-to-rural markets.[30] Such a comprehensive approach is unique to this study, and allows us to examine the relationships between world, regional, and internal Nigerian prices to a much greater extent than previous studies.

We focus on the markets for seven key food security crops (rice, maize, sorghum, millet, cassava, yams, and cowpeas) in Nigeria. This allows for a clearer understanding of

[30] "World" or "global" prices throughout refer to international price series from the U.S. Gulf, and also in Thailand for rice and South Africa for maize, that are commonly used in global agricultural commodity price analyses. Neighboring country prices are in fact "international" or border prices, but informal trade over land routes between neighboring countries is qualitatively different from "global" trade that arrives at ports. We will use the term "scope" to refer to the various distinctions across Nigerian markets highlighted in this paper.

how markets for these foods are linked, which is a prerequisite for design and implementation of market interventions and food policies (Lançon et al. 2011). Nigeria was chosen as a case study because its large geographic size, substantial share of regional agricultural production, and large population mean that food market conditions in Nigeria are influential throughout West Africa (Elbehri et al. 2013). Our results indicate that price spikes spillover across neighbor country borders more so than from global markets, with significant variations in transmission across crops and across regions within Nigeria. They also imply that other factors (e.g., weather) are likely to be relatively more important than international price spikes in determining prices in all examined markets in the short-run, especially in rural areas.

3.2 Previous Research on Food Price Transmission in Nigeria

Price transmission in Nigerian food markets has been the focus of previous studies, which inform the design of our empirical analysis. The pioneering study by Jones (1968) found price correspondence to vary between urban areas in Nigeria for a variety of foods. Nigerian grain markets, especially those in the north, have three primary flow types: 1) from rural producers to wholesale aggregators based in rural and urban markets (Hays and McCoy 1978; Okoh and Egbon 2005), 2) from urban wholesalers to rural wholesalers and retailers (Okoh and Egbon 2005), and 3) between wholesalers in urban markets (Hays and McCoy 1978). Local conditions (e.g., supply-use balances, transport links, and weather) are likely to explain variation in price transmission between different regions of Nigeria. For example, in a recent study, markets closer to maize production regions were found to have relatively greater market integration than these production zone markets and more distant ones (Ikudayisi and Salman 2014). Variation in price transmission across different crops has also been found within states (Momoh and Agbonlahor 2007). In addition to spatial variation in price correspondence, market linkages have also been found to vary over time. Specifically, Delgado (1986) found relatively less trader facilitated transactions between markets during harvest than in non-harvest periods.

Abbott and Borot de Battisti (2011) and Baltzer (2015) found evidence of high world price transmission to Nigerian cereals (rice, maize, millet, and sorghum) markets during the period of 2005-09 (which includes the 2007-08 “food crisis”). We expand on their analysis through inclusion of additional market scopes and crops (cassava, yams, and cowpeas), as well as using longer time series.

Price transmission between neighboring countries and Nigerian markets has, to our knowledge, not yet been extensively studied. Terpend (2006) and Galtier (2009), however, observed substantial trade in cereals and cowpeas across West Africa[31], which is consistent with UN Comtrade data for some countries and crops in the region (mainly between Nigeria and Niger for coarse grains[32]). Krugman (1991) found that, in general, neighbor country trade is much more sizable and regularly occurring than that between distant countries, and Baffes, Kshirsagar, and Mitchell (2015) found neighbor country grain price linkages to be stronger than those with global markets. These research findings and regional market observations motivate estimation of food price linkages between Nigeria and its neighbors in West Africa.

These previous studies of price transmission at different scopes (world, neighbor country, between urban areas, and between urban and rural areas) for Nigerian food markets inspired this combined comprehensive analysis of price transmission at all market scopes to allow for direct comparison. This empirical analysis is feasible because of the expansion of developing country food price databases that are now available after the “food crisis” of 2007-08. Sources such as the Global Information and Early Warning System (GIEWS) of the Food and Agriculture Organization of the United Nations (FAO) and the World Food Programme (WFP) provide rich price data series for Nigeria’s neighbor country markets. Nigerian urban and rural prices, unavailable for post-2007-08 “food crisis” analyses such as that by Olomola (2013) but used in the recent study by Ikudayisi and Salman (2014), became available in 2014 via release by the Nigerian National Bureau of Statistics (NBS).

[31] Terpend (2006) also describes regional trade in cassava and yams as limited primarily to coastal countries and their neighbors, and in substantially smaller quantities than trade in cereals and cowpeas.
[32] No database, including UN Comtrade, reports cowpea trade between Nigeria and its neighbors. Langyintuo, Lowenberg-DeBoer, and Arndt (2005), however, provide estimates of the quantities of cowpeas informally traded in the region using data obtained from government statistical service departments of analyzed regional countries.

3.3 Theoretical and Empirical Frameworks

The starting point for description of the theoretical relationship between prices in the analyzed markets is the law of one price (LOP). Under the LOP, prices of a homogeneous commodity in spatially separated markets are equal due to arbitrage by traders (Baffes, 1991). We begin with a base LOP price relationship for a food commodity in Nigeria that is imported from world markets in any period:

$$p = p^w e = p^*, \tag{1}$$

where p is the price in a Nigerian market in Nigerian Naira per kilogram, p^w is the "world" price in foreign currency units per kilogram, and e is the exchange rate in Nigerian Naira per foreign currency unit. The convention of past price transmission studies, adjusting world prices by the exchange rate, is maintained[33], so a new exchange rate adjusted world price is defined as p^*.

We sequentially add factors that could affect the LOP relationship in equation (1) both through adjustment in the level of the domestic price and the degree to which these prices co-move. We focus on general types of factors based on whether or not they may vary systematically with the world price, and discuss which factors are relevant in the Nigerian context. We describe the factors that vary systematically with the world price in detail because in some cases large margins between world and domestic prices are observed; and, more importantly, doing so provides theoretical explanation for the possible existence of price transmission parameter estimates that are significantly greater or less than one[34].

Some factors influence domestic market prices, but are independent of changes in the world price. Such factors could include, for example, transactions costs (e.g., shipping

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[33] While it is commonplace in the price transmission literature to adjust prices to common currency with an exchange rate, there is less consistency with regard to the use of nominal or real prices. Additionally, if deflated, the chosen index by which to deflate varies across studies as well. Nominal prices are used here because it is more consistent with LOP theory. See appendix 3A for further discussion of this issue.

[34] The perfect competition assumption (and its associated characteristics of such markets) of LOP theory implies that price transmission parameter estimates equal to 1 in integrated markets, but less than 1 in perfectly competitive but poorly-integrated markets (Minot 2011). By implication, an estimated price transmission parameter that is greater than 1 applies in markets for which the perfect competition assumption and its associated characteristics do not apply.

services) that are charged on a per ton basis (Timmer 1974). We define these factors as the variable f, and add them to the world prices in equation (2) such that in each period:

$$p = f + p^*. \tag{2}$$

These transactions costs may be large and may vary over time, but unless they vary with the world price, changes in f are captured in the error term of a regression on equation (2). The commodity is importable (i.e., arbitrage is profitable) if $p \geq f + p^*$ (Moser, Barrett, and Minten 2009). Work on "parity bounds" emphasizes that a good may sometimes be an exportable or sometimes an importable, but becomes non-tradable when transactions costs make both imports and exports too expensive (e.g., Barrett and Li 2002). The degree to which the domestic and world price co-move adjusts if the commodity becomes non-tradable ($p^* - f^* < p < f + p^*$) where f are import costs and f^* are export costs. In such a case, prices move independently, appear "segmented", and are determined by prices in other markets and/or local conditions.

Another set of factors, those for which a change in the world price directly adjusts the domestic price, have a systematic relationship with the world price. Such factors could include working capital (Timmer 1974; Dawe and Maltsoglou 2014) or (constant) ad valorem tariffs. We account for these factors through the parameter m, and add it to equation (3) such that it reflects proportionality to the world price:

$$p = f + p^*(1 + m). \tag{3}$$

Increases (decreases) in p^* increase (decrease) p by the same proportion determined by the magnitude of m.

Most research, including ours, presumes that proportional transactions costs other than tariffs are small (Dawe and Maltsoglou 2014; Miljkovic 1999; Fafchamps and Gabre-Madhin 2001; and, Goodwin, Grennes, and Wohlgenant 1990). Factors that might make margins proportional include trade policy, market power, and quality differences.

Tariffs may raise price transmission parameter estimates above one (reflected as a direct upward proportional adjustment to the domestic price in equation (3)), but endogenous policy responses (e.g., variable levies) may reduce transmission parameters all the way to zero (Abbott 1979; Bredahl, Collins and Meyers 1979). In Nigeria, observed ad valorem tariffs are only relevant for some crops and in some years[35]. They sometimes exhibit characteristics of a poorly implemented variable levy, and are generally low in most years relative to the large margins observed for maize and rice[36].

Perceived quality differences may account for large margins and limit the manner in which the domestic and imported good are substitutable, but the degree to which these would relate to the world price varies in different contexts. If the goods are imperfectly substitutable, there is less world to domestic price transmission (Minot 2011). In the case of Nigeria, some quality differences have been observed, especially between imported and domestic rice (Johnson, Takeshima, and Gyimah-Brempong 2013). We control for this by separately analyzing imported and local rice. Moreover, we find the correlation between the domestic premium on imported rice and the world rice price varies across regions, at 83% and -1% for the Kano and Lagos commercial hubs, respectively. This implies that quality premiums adjust systematically with the world rice price to a large degree in Kano, but other factors (e.g., trade policy and/or mark-ups) are predominant in Lagos. In the case of maize, the world price is for yellow maize used as feed, while the domestic price is for white maize, a food crop that should demand a premium and is substitutable with imported maize to only a limited degree.

Mark-ups by traders of imported goods with market power are expected to increase world to domestic price transmission (Frankel, Parsley, and Wei 2012). The relationship between mark-ups and world prices is, however, based on trader behavior that may not be systematic. Mark-ups have been found to be somewhat common in U.S. agricultural commodity markets (Applebaum 1982; Schroeter 1988) and in international

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[35] United Nations Conference on Trade and Development (UNCTAD) Trade Analysis Information System (TRAINS) data on Nigerian tariffs for rice and maize for 2001 to 2010 are as follows. The rice tariffs were 100% in 2001, 75% in 2002, uncertain in 2002 and 2003, 50% in 2005 and 2006, uncertain for 2007 and 2008, and 5% for 2009 and 2010. For maize, the tariffs were 25% in 2001, 70% in 2002, uncertain in 2003 and 2004, 5% in 2005 and 2006, uncertain in 2007, and 5% for 2008 to 2010.

[36] If one assumes that the tariffs stay the same for the years for which tariff data are missing, the correlation between world maize prices and Nigerian maize tariffs is -0.51, and for rice it is -0.58. If the years for which there are missing tariff data are excluded, these correlations are -0.44 and -0.54 for maize and rice, respectively. Under a perfectly implemented variable levy system, these correlations would be -1. See Johnson and Dorosh (2015) for further description of poor implementation of rice levies in Nigeria for the recent period of 2008-13.

settings (Sheldon and Sperling 2003), and are plausibly relevant in Nigeria too[37]. We rely on the literature of both price transmission and "new industrial organization" to inform our empirical framework when this may be the case.

3.3.1 Guidance from the price transmission and "New" Industrial Organization literatures

Price transmission literature generally focuses on whether there is full (an equal change in prices) or incomplete (a less than equal change in prices) price transmission. Data examined is limited to prices at different points in space and time. In this literature, incomplete or greater than full price transmission is often attributed to unobserved factors (e.g., market imperfections, transactions costs) (Baffes and Gardner 2003).

The "new" industrial organization literature provides an alternative explanation for greater than full price transmission. Within this literature, price mark-ups above marginal cost are observed in any market that is imperfectly competitive, and they are a function of the market structure (i.e., the number and size of firms) and the market demand elasticity (Applebaum 1982). In the presence of mark-ups, transmission from world to domestic prices is higher (Frankel, Parsley, and Wei 2012), so, in such a case, it is possible that there is greater than full price transmission. This literature uses the same type of data as the price transmission literature, but attributes certain results to market power rather than unobserved costs. Transactions costs that do not systematically vary with input prices (world prices in the price transmission case) are routinely assumed to identify marginal cost.

Based on the Nigerian market context discussed above, we argue that both the price transmission and "new" industrial organization literature provide relevant theoretical insights into price relationships in these markets. Given the current somewhat problematic nature of measurement of these factors that influence relationships (especially for trade policy and mark-ups), we rely solely on price data. Bresnahan (1989) argued that there are commonly unmeasured aspects of price relationships, but there is still much to learn from inclusion of only observed prices in an empirical model. In place

[37] Informal consultations with Nigerian stakeholders and limited data obtained from industry representatives are supportive of this conjecture.

of direct control of unmeasured factors, careful interpretation of the coefficients of estimated price relationships in light of key market structure contexts allows for insights on the relevance and relative importance of unmeasured factors (Bresnahan 1989).

3.3.2 Empirical framework: cointegration

We proceed with the commonly employed price transmission cointegration framework, which is consistent with LOP theory (Ardeni 1989). We implement a version of the two-stage cointegration method of Engle and Granger (1987). In the first stage, a linear model that includes the levels of prices in a reduced form of equation (3) is estimated:

$$p_t = \alpha + \beta p_t^* + u_t, \tag{4}$$

where p_t is the Nigerian price in Nigerian Naira per kilogram in month *t*, p_t^* is the exchange rate adjusted world price in Nigerian Naira per kilogram in month *t*, α is the intercept parameter that captures transactions costs and other factors that do not vary systematically with the world price, β is the long-run world to Nigerian price transmission parameter, which also captures other factors that vary systematically with the world price, and u_t is a random error for period *t*. If $\hat{\beta}$ is equal to 1 then results are consistent with markets that are perfectly competitive; if $\hat{\beta}$ is less than 1, then results are consistent with imperfectly integrated markets; and, if $\hat{\beta}$ is greater than 1, then results are consistent with imperfect competition, and $\hat{\beta} - 1$ is the size of the mark-up. However, if there is imperfect competition in imperfectly integrated markets, then interpretation of the estimate of $\hat{\beta}$ is unclear.

In the second stage, an error correction mechanism (ECM) model is estimated in order to account for short-run dynamics. These time elements are important because some market arbitrage activities may occur with a lag (Ravallion 1986). The estimated ECM model has a form similar to that outlined in Banerjee et al. (1986):

$$\Delta p_t = -\gamma \hat{u}_{t-1} + \delta \Delta p_t^* + \varepsilon_t, \tag{5}$$

where $\Delta p_t = p_t - p_{t-1}$, $\Delta p_t^* = p_t^* - p_{t-1}^*$, $\hat{u}_{t-1}$ are the lagged residuals from the associated levels model in equation (4), δ is the short-run price transmission parameter, which measures instantaneous price transmission between markets, and, γ is the error correction parameter, which measures the average degree of adjustment toward long-run equilibrium in each month (Baffes and Gardner 2003).

The ECM model results were used to calculate the degree of adjustment to long-run equilibrium over time. Calculations of the degree of adjustment values follow Baffes and Gardner (2003). Implementation of their method means that we define k as the equilibrium adjustment that occurs in *n* months, and its estimated value ($\hat{k}$) is:

$$\hat{k} = 1 - \left(1 - \hat{\delta}\right)(1 - \hat{\gamma})^n, \tag{6}$$

such that $\hat{k}$ is the proportional adjustment toward long-run equilibrium that occurs in *n* months.

3.3.3 Econometric issues

Stationarity of the series was tested using the Augmented Dickey-Fuller (ADF) test of Dickey and Fuller (1979 and 1981) and the Phillips-Perron (PP) test of Phillips and Perron (1988). With only a few exceptions, series were found to be nonstationary, but stationary in first differences. This implies that most series are integrated of order 1 (i.e., I(1) in levels, and I(0) in first differences)[38].

Cointegration was tested using both levels model residual stationarity tests (Engle and Granger (1987)), as well as tests on the statistical significance of the error correction parameter ($\hat{\gamma}$) in the ECM model (Banerjee et al. 1986). Levels model residuals stationarity was tested using the ADF and PP tests (Baffes and Gardner 2003), where rejection of the null hypothesis of nonstationarity indicates cointegration.

Baffes and Gardner (2003) argued that LOP should hold over the long-run. Therefore they imposed $\beta = 1$ as a constraint on the levels model, although their results rejected this constraint in many cases. This "unitary cointegration" (which imposes $\beta = 1$) was also tested through ADF and PP tests on the stationarity of price spreads. Cointegration will be found, but unitary cointegration rejected, both when

[38] Out of the 183 price series included in the analysis, there were 10 series for which the null hypothesis of nonstationarity was rejected at the 5% statistical significance level by both the ADF and PP tests. Of those 10 series, 8 were in the urban-to-rural set that has the lowest number of observations (48, see the data section below). For the rural price set (and only this set), there were also 5 out of 48 series for which nonstationarity in first differences was not rejected, but in none of these 5 cases did this apply for both the ADF and PP tests.

market power raises β above 1 and when imperfect price transmission lowers it below one.

Cointegration test results for those models discussed in the results section are provided in the comprehensive levels models results in appendix 3D of this chapter. For all models, evidence of cointegration was found using at least 2 of the 3 cointegration tests at 5%. Unity cointegration results are also reported there, showing those cases as described above where cointegration is found, but not unitary cointegration[39].

3.3.4 Expected empirical results

LOP implies perfect market integration and competition, which Goodwin and Schroeder (1991) define as the case where the prices are cointegrated and there is both full ($\beta = 1$) and instantaneous ($\delta = 1$) price transmission. The markets for which trade plausibly occurs regularly throughout a marketing year (e.g., coarse grain trade between Nigeria and its neighbors (Galtier 2009)) are those for which full price transmission is most plausible ($\beta = 1$). The markets for which trade only occurs during a few months of a marketing year (e.g., trade between urban and rural markets (Delgado 1986)) are expected to have incomplete price transmission ($\beta < 1$). The markets for which there are plausibly transactions costs or quality premiums that have a systematic relationship with the price, and/or mark-ups captured by traders are those for rice and coarse grains imported from global markets. In the models for these markets, there may be greater than full price transmission ($\beta > 1$). It is also conceivable that there are both imperfectly integrated and imperfectly competitive markets, but estimation expectations in such cases are indeterminate.[40]

[39] Unitary cointegration failure, defined as when both the ADF and PP statistics for the unitary cointegration test are not statistically significant at the 5% significance level, occurred in the following models. For each respective crop, the number of corresponding unitary cointegration failures for world (6 models), neighbor country (6 models), urban (5 models), and rural (6 models) sets are listed in parentheses: imported rice (5, 0, 0, 0), maize (3, 0, 1, 2), local rice (1, 0, 0, 2), cassava (0, 0, 0, 0), yams (n/a, 0, 0, 0), and cowpeas (n/a, 2, 0, 2). Of the 3 maize world market unitary cointegration failures, none were for those associated with Northern Nigerian markets. These unitary cointegration results are in appendix 3C of this chapter.

[40] Statistical tests can indicate whether data is consistent with a particular theoretical explanation, but in this case cannot distinguish between alternative explanations.

3.4 Data and Summary Statistics

3.4.1 World prices

World Prices were obtained from the World Bank (WB), International Monetary Fund (IMF), Global Information and Early Warning System (GIEWS) of the Food and Agriculture Organization of the United Nations (FAO)[41], FAO[42], and the South African Futures Exchange (SAFEX)[43]. For maize and rice, series included in the analysis were those for countries from which UN Comtrade data show records of imports by Nigeria since 1995.

3.4.2 Neighbor country prices

Prices for Benin, Togo, Ghana, Mali, Burkina Faso, Niger, Chad, and Cameroon were obtained from GIEWS and the World Food Programme (WFP) Monthly Price Data Analysis Tool. These price data were available for all food security crops included in the analysis, but are relatively sparse for cassava, yams, and cowpeas.

These data are often available for more than one city in our neighbor countries, so choices were made about which prices to include. In the approach taken here, two cities were chosen for each country to allow for some regional variation. Where possible, cities were chosen for each country to include an inland city, connected by roads to Nigeria, and a port city, more closely linked to markets outside West Africa. The countries and cities chosen were (moving geographically in a circle from Nigeria west to north to east to south): Cotonou and Malanville, Benin; Lomé and Korbongou, Togo; Accra and Bolgatanga, Ghana; Bamako and Mopti, Mali; Ouagadougou and Dori, Burkina Faso; Niamey and Maradi, Niger; N'Djamena and Moundou, Chad; and, Yaoundé and Garoua, Cameroon (figure 3-1).

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[41] The GIEWS data for world prices are from the "Food Price Monitoring and Analysis Tool" database, within which both "domestic" and "international" price series are reported. The Bangkok, Thailand cassava price is also included as a world price, but was obtained from the "domestic" GIEWS dataset.
[42] The FAO has two primary price databases: 1) GIEWS and 2) "FAO Prices". "FAO Prices" is a more limited dataset with only globally traded food items.
[43] SAFEX white maize price data were obtained from the Johannesburg Stock Exchange.

3.4.3 Nigerian state level prices

Nigerian prices are state level retail prices, aggregated to statewide averages, obtained from the Nigerian National Bureau of Statistics (NBS). The urban prices are monthly observations, and are, in most cases, available from January 2001 to December 2010. The rural prices are monthly also, but are only available for January 2007 to December 2010. A state with the major urban center in each of the six major socioeconomic regions, as defined in the Nigerian NBS General Household Survey-Panel 2010-2011 Basic Information Document, was included in the analysis. These states are also shown in figure 3-1.

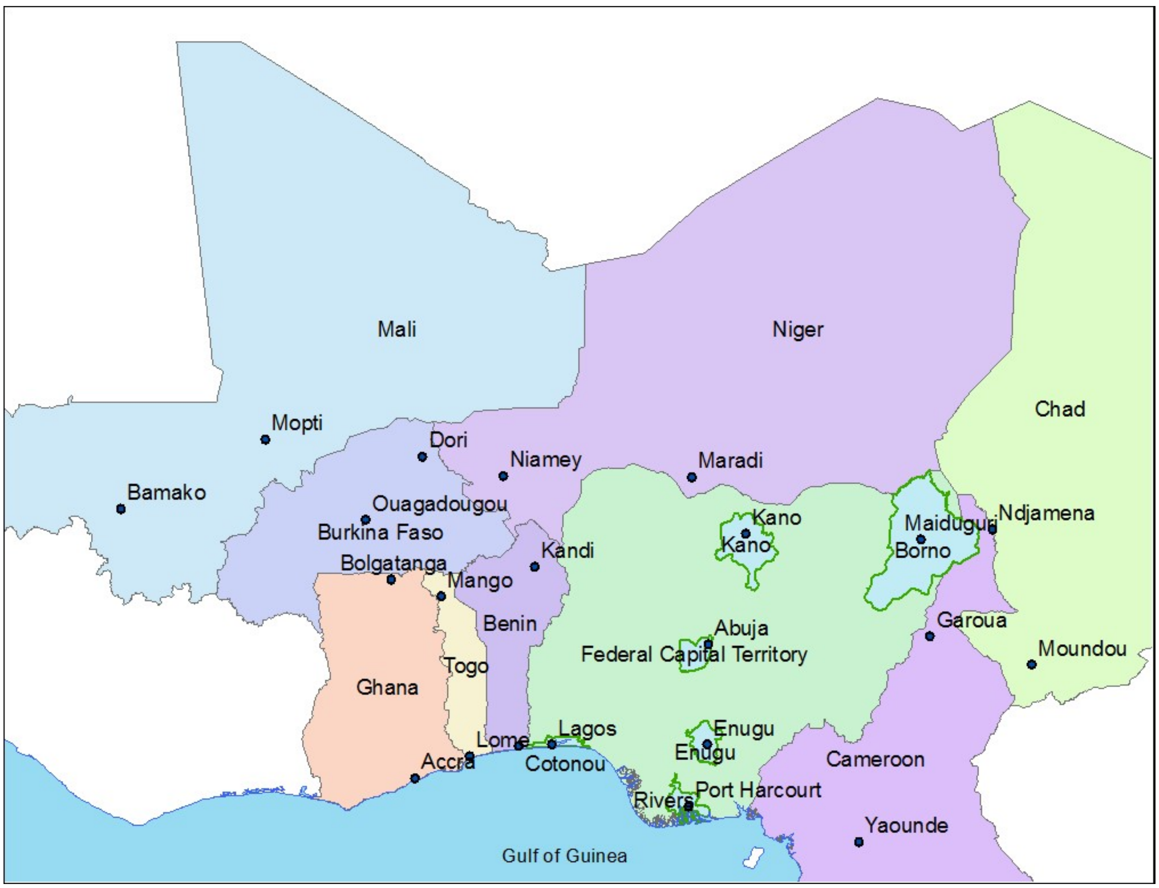

Figure 3-1: Map of Nigeria and neighbor countries

Sources: DIVA-GIS and Natural Earth Data.
Note: Malanville, Benin and Korbongou, Togo were not included in the DIVA-GIS data. The nearby cities of Kandi, Benin and Mango, Togo are included on the map to show where Malanville and Korbongou are located.

3.4.4 Exchange rates

World prices were adjusted to Nigerian Naira per kilogram using exchange rate data. Most of the world prices were listed in terms of in U.S. Dollars, and for these series, the exchange rate used was the Nigerian Naira per U.S. Dollar exchange rate from the IMF's International Financial Statistics (IFS) database. The GIEWS "domestic" neighboring country prices were most commonly in U.S. Dollars or West African CFA Franc. The CFA Franc to U.S. Dollar exchange rate was also obtained from IFS. Exceptions include the cassava prices from Thailand, prices of a few crops in Ghana, and rural maize prices in South Africa. For these prices, the Thai Baht to U.S. Dollar and South African Rand to U.S. Dollar exchange rates were obtained from the Federal Reserve Economic Database (FRED) of the St. Louis Federal Reserve, and the Ghanaian Cedi to U.S. Dollar exchange rate was obtained from the Bank of Ghana. After these were converted to U.S. Dollars, they were converted to Nigerian Naira per kilogram using the IMF IFS exchange rate series.

3.4.5 Data issues

There were some data issues with the Nigerian NBS price data. First, there are no data for any of the crops included in the analysis for Borno State for 2001, so these series all begin in January 2002. Data are also missing for Kano State for all crops except cassava and cowpeas for 2008. The millet data for 2008 were clearly subject to transcription error, and so were excluded. Nevertheless, millet results were broadly similar to the results for the other coarse grains so our discussion of patterns applicable to coarse grains remains relevant for millet.

3.4.6 Price series summary statistics

The summary statistics, as well as plots of select price series over time, for the prices in our models are included in appendix 3B of this chapter. For the period of analysis, world prices for maize, rice, and cassava were substantially lower than those in the Nigerian commercial hubs for these crops (Kano and Lagos, respectively). Standard deviations (SD) for the world prices are all substantially lower than those in Nigeria, especially for imported rice. Mean prices in neighbor country markets were lower than

Nigerian commercial hub means for imported rice, cassava, yams, and cowpeas, but higher for local rice and maize. These disparities in means and SDs are generally much smaller than those between world and Nigerian commercial hubs.

3.5 Empirical results

Each of the world set models (equations 4 and 5) included price series corresponding to the previously described world price databases, which vary somewhat across sources. For maize, there are 7 models including price series from the U.S., Argentina, and South Africa; for rice (both imported and local), there are 13 models with price series from Thailand, Vietnam, the U.S., Uruguay, and India; for sorghum, there are 3 models with prices from the U.S. Gulf; for cassava there is 1 model with prices from Bangkok, Thailand.

The neighbor country market set of models is comprised of those for which data were available from the 16 cities described above. In this set, there are: 14 maize models; 14 rice models for each type (imported and local); 13 sorghum models; 6 cassava models; 4 cowpeas models; and, 2 yams models. The commercial hub-to-urban and urban-to-rural sets of models are comprised of models associated with each of the 6 states for each crop.

In order to choose which results to report[44], goodness-of-fit statistics from the estimated levels models were compared across models from each set (except for the urban-to-rural set for which results for all models in the set are reported) and for each crop. For the world and neighbor country market model sets, the model with the highest adjusted-R^2 was chosen for each crop. In the commercial hub-to-urban set, for each crop with multiple potential hubs, the primary commercial hub was identified as that among of the contenders that was associated with the highest adjusted-R^2 value[45]. Since results for

[44] Comprehensive results for the levels models are in Appendix 3D, and for the ECM models in Appendix 3E.

[45] To do this, a few potential contending hubs were chosen based on the presence of a known commercial hub market, proximity to major producing areas using state level production data, and secondary sources such as those that describe substantial imports through country ports located in Southern Nigeria (Johnson, Takeshima, and Gyimah-Brempong 2013). Kano was identified to be the likely commercial hub for maize, sorghum, millet, and cowpeas, because Kano is home to Dawanau Market, the hub market for food crop trade across West Africa (Terpend 2006). Coarse grains and cowpeas are also grown in Kano's Northwest region, or in the other nearby regions (Northeast or North-Central). The potential hubs for imported and local rice, due to proximity to ports and/or substantial nearby production, were: Lagos, Rivers, Enugu, and

maize, sorghum, and millet are broadly quite similar, only maize results are reported here.

For simplification of results reporting and presentation, figures display the key parameter estimation results from both the levels and ECM models and to allow the reader to visualize the observed regional variation in results. The contents of each figure (3-2 through 3-7) are described below figure 3-2.

3.5.1 Maize

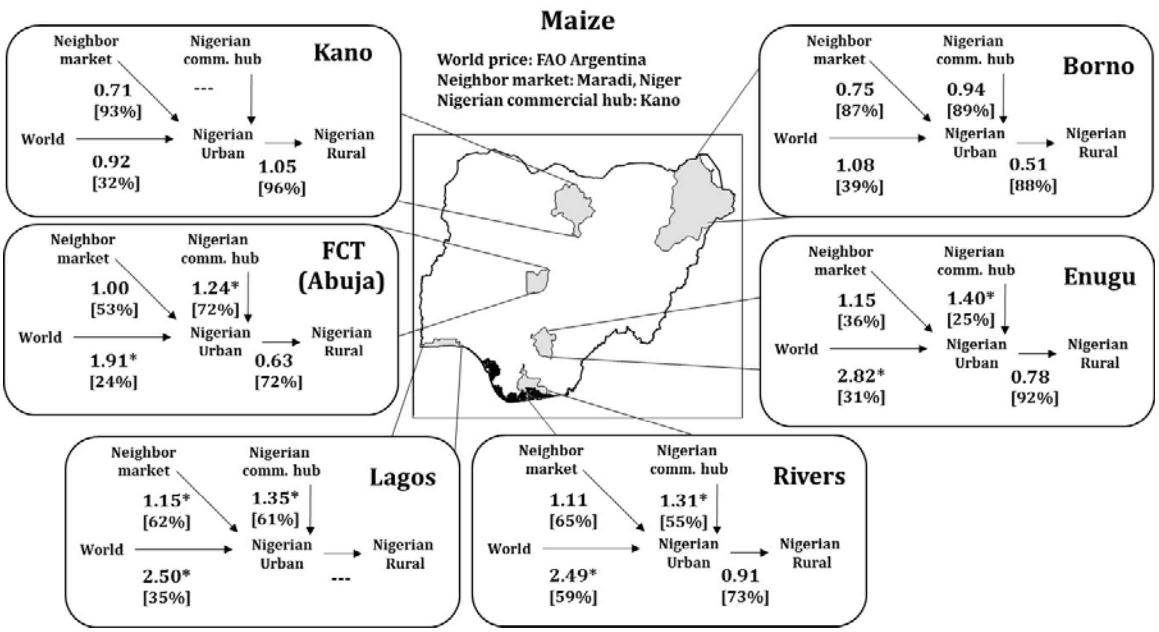

Figure 3-2: Summarized empirical results for levels and ECM models for maize

Note: Estimated Price Transmission (EPT) parameters ($\hat{\beta}$) are statistically different than 0 for all models. The EPT parameters have a star (*) next to them if they are statistically significantly greater than 1 at the 5% significance level. The 3-month degree of adjustment value is presented in brackets […] below the EPT parameters as a percentage. If the estimated error correction parameter ($\hat{\gamma}$) was not statistically significant at the 5% significance level, then the results were excluded because there is insufficient information for accurate calculation of the 3-month equilibrium adjustment value[46].

Kano; for cassava they were: Lagos and Kano; and, for yams they were: Federal Capital Territory (FCT) (Abuja) and Kano.

[46] That the error correction parameter is not statistically significantly different from zero at the 5% significance level does not imply that these series are not cointegrated. In appendix 3D of this chapter, which has cointegration results for the reported models, it is shown that the models for which the error correction parameter is not statistically significantly different from zero at the 5% level have residuals that are stationary at the 5% significance level (at least) based on the ADF and PP statistics. Given that all models show evidence of cointegration based on at least 2 of the 3 cointegration tests undertaken at this chosen significance level, we consider all reported series as cointegrated. Therefore, we focus on hypothesis testing of the parameters in the reported results.

Summarized empirical results for maize are shown in figure 3-2. Estimated price transmission (EPT) parameters for all models were statistically significantly greater than 0, which suggests that maize prices in the analyzed markets co-move to at least some degree. The EPT parameters were statistically significantly greater than 1 in models for the Southern and Central Nigerian states of Lagos, Rivers, Enugu, and FCT (Abuja). The highest degree of 3-month adjustment value for the world set is only 59%, which suggests that Nigerian maize prices adjust to world prices with a long lag. The 3-month degree of adjustment values are higher for the neighbor market models than world models for all states, and approach 100% for the Kano and Borno State models. Commercial hub-to-urban EPT parameters were statistically significantly greater than 1 in some cases, and broadly had low 3-month degree of adjustment values (an exception was Borno State). EPT parameters for the urban to rural set are broadly lower than for all other sets (Kano State was an exception). These results suggest rural maize prices do not co-move with those in urban areas to a high degree. The patterns of estimates for maize were broadly similar for sorghum and millet.

3.5.2 Imported Rice

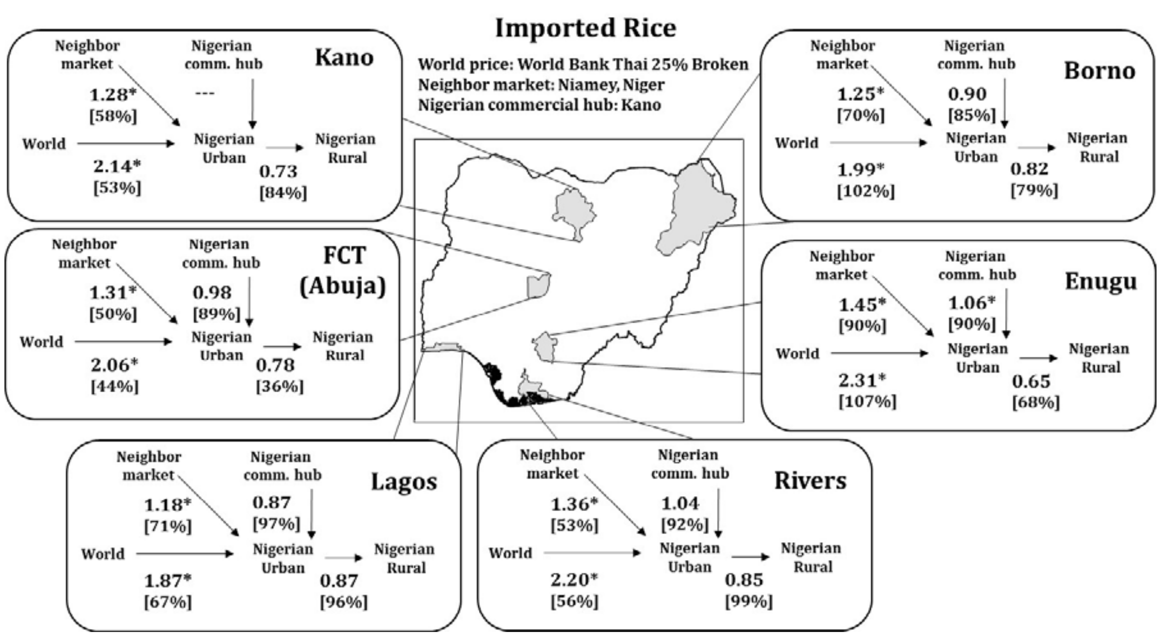

Figure 3-3: Summarized empirical results for levels and ECM models for imported rice

See figure 3-2 for the description of information for reported parameter estimates and associated statistics.

Figure 3-3 includes summarized results for imported rice. All EPT parameters were statistically significantly greater than 0. A notable result is that the EPT parameters were statistically significantly greater than 1 for all models in the world set, and often had magnitudes near 2. The degree of 3-month adjustment to the world price exceeded 100% for the Enugu and Borno State models, and ranged from 44% to 67% in the other states. These results suggest that equilibrium adjustment to world prices is considerably faster for rice than coarse grains, especially in some regions. EPT parameters for all neighbor country models were also statistically significantly greater than 1. EPT parameters for the commercial hub-to-urban set are all near 1 and all corresponding 3-month adjustment values were above 80%, which implies that imported rice prices in urban areas in Nigeria equilibrate quicker than those of coarse grains. There was wide variation in degree of adjustment values for the urban-to-rural set (36% to 99%). This result implies that urban areas have stronger linkages with each other than with rural areas.

3.5.3 Local Rice

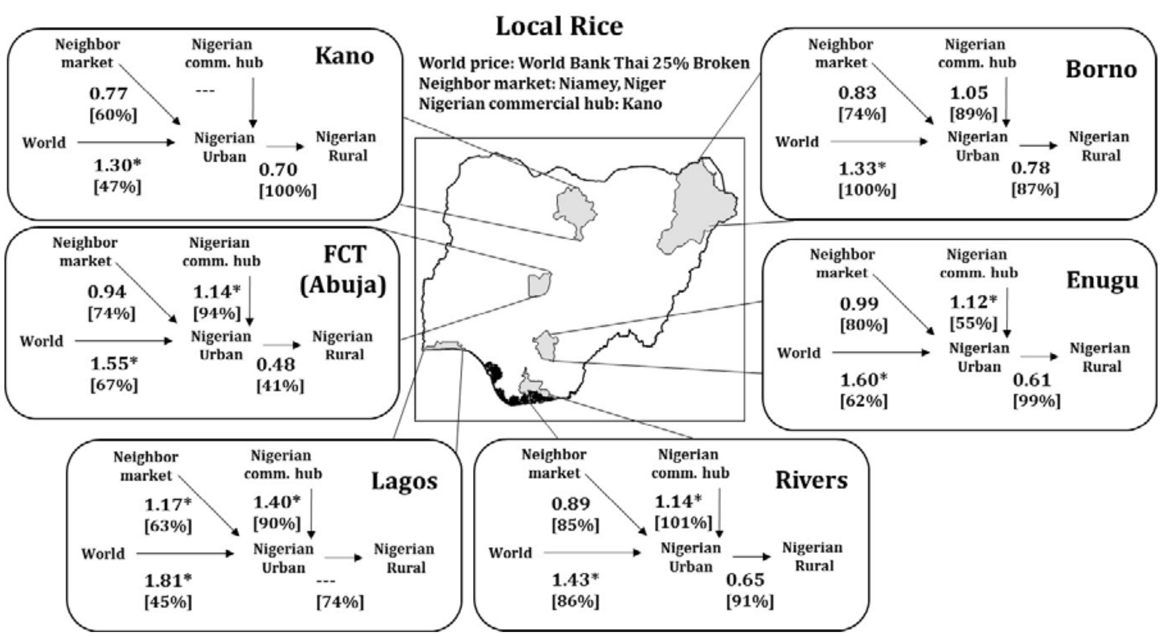

Figure 3-4: Summarized empirical results for levels and ECM models for local rice
See figure 3-2 for the description of information for reported parameter estimates and associated statistics.

Summarized empirical results for local rice are provided in figure 3-4. All EPT parameters are statistically significantly greater than 0. The magnitudes for the world set are all statistically significantly greater than 1, but smaller in magnitude than those of imported rice. Neighbor country model EPT parameters were also lower in magnitude than those for imported rice. Only the Lagos neighbor country model had an EPT parameter significantly greater than 1. EPT parameter magnitudes for the commercial hub-to-urban set, however, were more commonly greater than 1 for the local rice models than imported rice models. Similar to imported rice, 3-month adjustment speeds varied across regions, but were relatively high for all commercial hub-to-urban models (except for Enugu). The urban-to-rural 3-month adjustment values were broadly higher for local rice than imported rice for all states except Lagos and Rivers states in Southern Nigeria (where the major ports are located).

3.5.4 Cassava

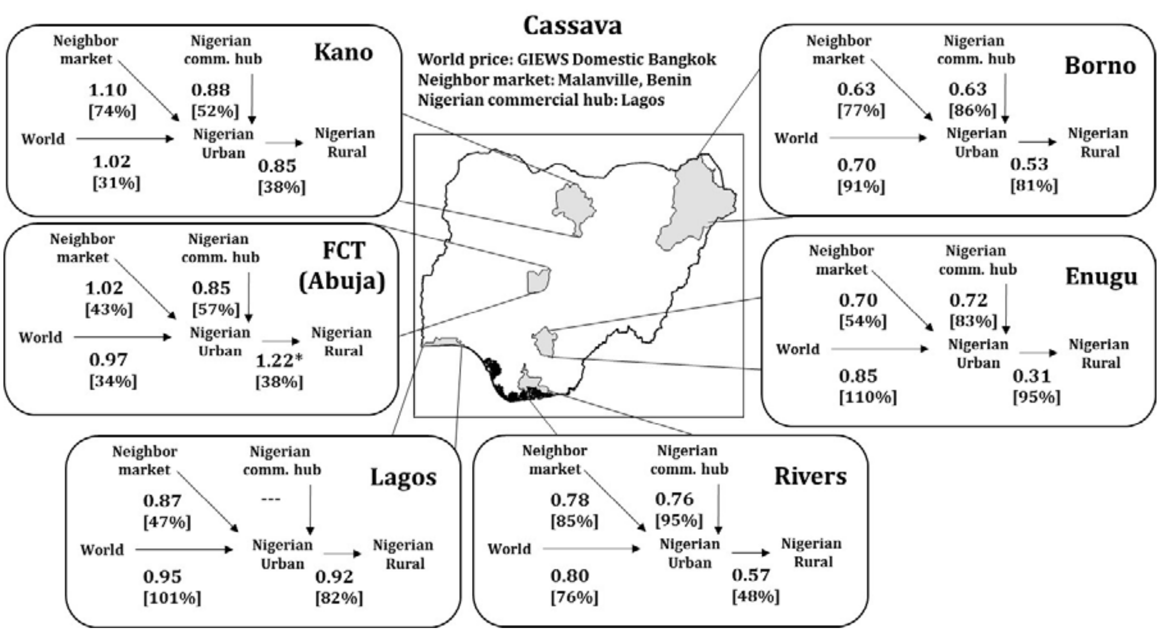

Figure 3-5: Summarized empirical results for levels and ECM models for cassava

See figure 3-2 for the description of information for reported parameter estimates and associated statistics.

Figure 3-5 includes summarized empirical results for cassava. All EPT parameters are statistically greater than 0. 3-month adjustment values to world prices varied greatly across regions. Those for Enugu and Lagos in Southern Nigeria exceeded 100%, implying rapid equilibrium adjustment, while those for Kano and FCT (Abuja) were only near 30%. For the Kano State case, higher 3-month adjustment to the neighbor market prices than world prices was found, but the opposite applied for Lagos. The 3-month adjustment values for the commercial hub-to-urban and urban-to-rural models had distinct regional variation. In Southern Nigeria, cassava price adjustment between urban areas and between urban and rural areas is rapid, but in Northern Nigeria it is slow.

3.5.5 Yams

Summarized empirical results for yams are included in figure 3-6. All EPT parameters are statistically significantly greater than 0. Relatively low neighbor market set EPT parameters were found for yams as compared to other crops. This suggests that Nigerian yam prices are more independent from changes in international yam prices than is the case for other crops. For the commercial hub-to-urban and urban-to-rural sets, estimated 3-month adjustment values were all above 50%, suggesting that there is somewhat rapid adjustment (especially relative to coarse grains) of yams prices throughout Nigeria.

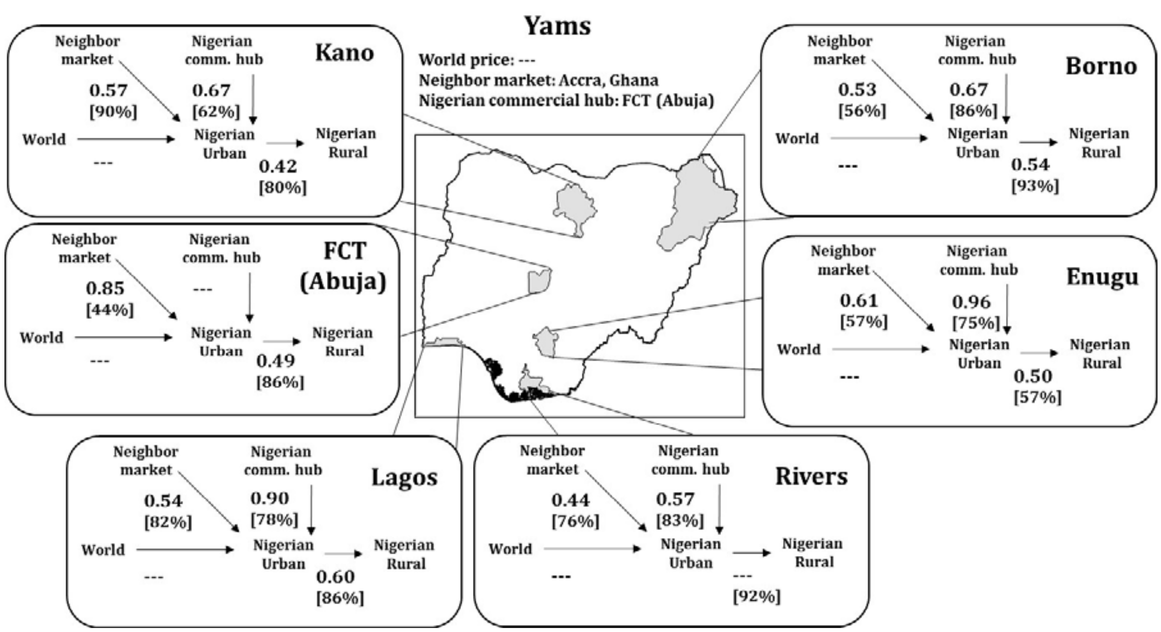

Figure 3-6: Summarized empirical results for levels and ECM models for yams

See figure 3-2 for the description of information for reported parameter estimates and associated statistics.

3.5.6 Cowpeas

Figure 3-6 displays summarized empirical results for cowpeas. For the neighbor market set, all EPT parameters were statistically significantly greater than 0. The 3-month adjustment values for this set, however, ranged from 30% to 51%, which suggest long lags in adjustment. There are higher 3-month adjustment values for the commercial hub-to-urban and urban-to-rural sets than for the neighbor country set. These results suggest that cowpea prices within Nigeria are more highly linked than Nigerian and neighbor country prices. The 3-month adjustment values were higher for the urban-to-rural set than the commercial hub-to-urban set.

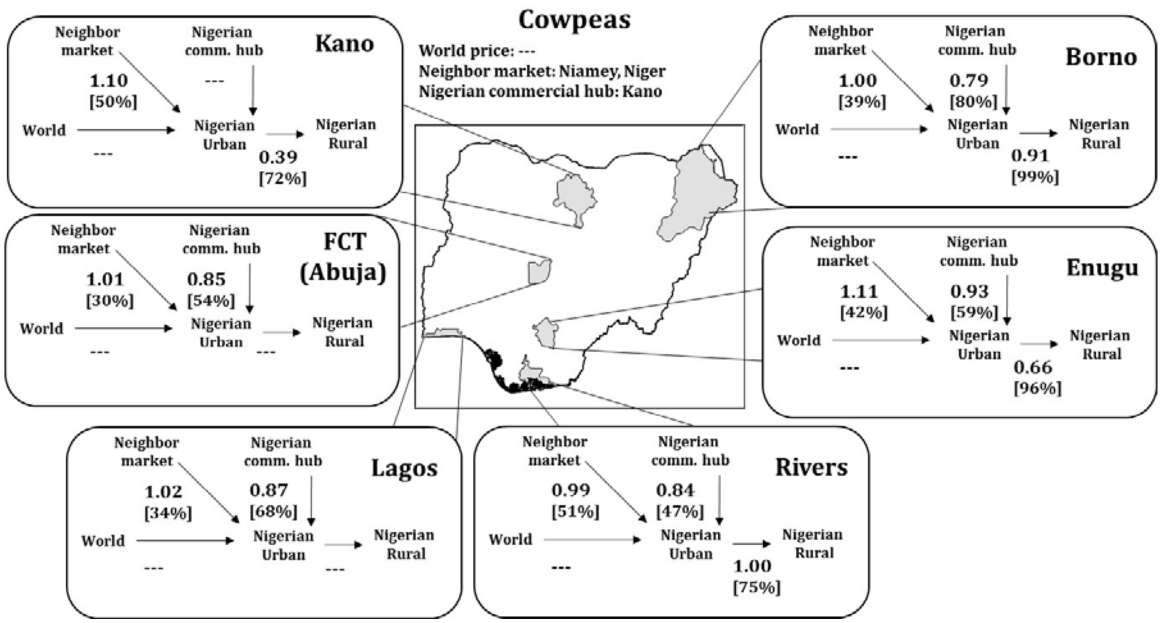

Figure 3-7: Summarized empirical results for levels and ECM models for cowpeas

See figure 3-2 for the description of information for reported parameter estimates and associated statistics.

3.5.7 Comparison across models and sets

Table 3-1 includes the average adjusted-R^2 values for the reported levels models, average estimated EPT parameters from those levels models, average adjusted-R^2 values from corresponding ECM models, and average 3-month adjustment values from the ECM models for results in figures 3-2 through 3-7, in order to facilitate comparison between models and across crops.

The world models for coarse grains and cassava have lower levels model adjusted-R^2 values than those for imported and local rice, but the opposite was found for the neighbor market set. These results imply that Nigerian coarse grains and cassava have relatively higher price correspondence with neighbor countries than with those in world markets. Hence, trade for coarse grains is mostly with neighbors, whereas substantial rice trade is with global sources. Yams models in the neighbor country set have the lowest levels model average adjusted-R^2 values of all neighbor country models. These results suggest that other (local) factors are relatively more important than trade in explaining yam price variation. The highest levels model average adjusted-R^2 values of all models in table 3-1 are those for the commercial hub-to-urban set for imported rice, which was 0.90, and those for local rice and cowpeas were above 0.80. Average levels adjusted-R^2 values (and EPT parameters) were higher for the commercial hub-to-urban set than the urban-to-rural set. This implies that urban market prices are linked to one another to a greater degree than are urban and rural prices.

Levels model EPT parameters are higher than 1 for maize, imported rice, and local rice in the world set, and for the neighbor country set for imported rice. These large EPT parameter magnitudes imply that these markets either have high transactions costs or quality differences between imported and local versions of these goods *that vary systematically with the border prices* for these foods, or there are mark-ups by importing firms (or all of these). In these cases, cointegration is not rejected, but unitary cointegration is.

Average adjusted-R^2 values for the ECM models are mostly substantially lower than those of the associated levels models (the exception is for yams in the neighbor country and urban-to-rural sets). These values, however, are higher in most cases for the sets within Nigeria than those with international markets. Coarse grains are exceptional in that there are higher adjusted-R^2 values for the ECM models for the neighbor country set than commercial-hub-to urban set. Again, this is consistent with the strong linkages between Nigerian coarse grain markets (especially in the north) and those in neighbor countries. These same patterns broadly apply for the average 3-month degree of adjustment values. It is notable that none of the sets had an average adjustment close to full adjustment after 3-months, which suggests broadly long lags in price adjustment in all examined markets.

Table 3-1: Average adjusted-R^2 and EPT parameter values for levels models, and average adjusted-R^2 and degree of adjustment in 3 months for ECM models for results in figures 3-2 through 3-7

		World	*Neighbor country*	*Commercial hub-to-urban*	*Urban-to-rural*
Levels adj. R^2	Maize	0.47	0.68	0.57	0.61
	Imported Rice	0.86	0.87	0.90	0.70
	Local Rice	0.79	0.80	0.84	0.46
	Cassava	0.54	0.58	0.64	0.53
	Yams	…	0.21	0.50	0.20
	Cowpeas	…	0.61	0.81	0.69
Levels EPT values	Maize	1.95	0.98	1.25	0.78
	Imported Rice	2.10	1.31	0.97	0.78
	Local Rice	1.50	0.93	1.17	0.64
	Cassava	0.88	0.85	0.77	0.73
	Yams	…	0.59	0.75	0.51
	Cowpeas	…	1.04	0.86	0.76
ECM adj. R^2	Maize	0.09	0.23	0.18	0.27
	Imported Rice	0.20	0.19	0.35	0.30
	Local Rice	0.21	0.22	0.30	0.32
	Cassava	0.18	0.18	0.24	0.23
	Yams	…	0.23	0.23	0.25
	Cowpeas	…	0.14	0.18	0.23
Degree of adjustment in 3 months	Maize	37%	66%	60%	70%
	Imported Rice	72%	65%	91%	77%
	Local Rice	68%	73%	86%	82%
	Cassava	74%	63%	75%	64%
	Yams	…	68%	77%	82%
	Cowpeas	…	41%	62%	57%

3.6 Concluding Remarks

This paper has three main findings, and the comprehensive study design added instructive nuances for each finding. First, crop tradability is found to be a key determinant of price transmission, consistent with the findings of Abbott and Borot de Battisti (2011), but also that tradability varies across crops and scopes of markets. Price correspondence between world rice prices and Nigerian urban rice (both imported and local) prices is strong for all regions. World coarse grain prices (maize and sorghum) do not correspond well with those in Nigeria. However, this does not mean that coarse grains are non-traded. Our results show strong price correspondence between Nigerian coarse grain prices and those of its neighbor countries in West Africa, even those for which there is currently sparse UN Comtrade data. Indeed, in some cases, linkages between neighbors and Nigerian markets were closer than those within Nigeria. The implications are that there is regular movement of coarse grains across borders throughout West Africa, and to a higher degree than they are imported by sea through Southern Nigerian ports. Cowpea results, and to a lesser extent those of yams and cassava, are also consistent with greater regional than global trade. These findings are consistent with cowpea trade estimates of Langyintuo, Lowenberg-DeBoer, and Arndt (2005) and observations of Terpend (2006), and Galtier (2009) of substantial trade in cereals and cowpeas (and cassava and yams in relatively smaller quantities) throughout West Africa. They also support the empirical results of Baffes, Kshirsagar, and Mitchell (2015) who found relatively greater coarse grain price correspondence among East African Countries than between those countries and global markets. Trade in rice occurs on road between Nigeria and its inland neighbor countries, but contrary to coarse grains, also to a similarly substantial degree through the ports in the south.

Our second key result is that local market conditions (e.g., supply-use balances, extreme weather anomalies) appear to matter for price transmission, especially in the short-run. Our results imply that local (or other) conditions matter for all examined crops, but most prominently for coarse grains and cowpea markets, reflected in both the substantial lags in adjustment across all markets and the low adjusted-R^2 of the ECM models. The implication is that price formation in local markets takes place primarily in local markets, even for crops that are widely traded between urban areas.

Our third key finding is that there are larger estimated price transmission parameters than would be expected under perfectly competitive and well-integrated markets, even with the presence of factors expected to reduce price transmission. These apply especially for rice and coarse grains in models for international markets. For coarse grains, this result is only relevant for Southern Nigeria, but is applicable in all regions for rice. In these cases, cointegration was found, but unitary cointegration, which imposes theoretical constraints from the law of one price, was rejected. The implications of these estimates is that there are either substantial transactions costs or quality differences that result in premiums for imported food *that vary systematically with the border price*, and/or mark-ups by traders that import coarse grains and rice on world markets. Evidence from Nigerian markets suggests that quality differentials exist, and may be systematically related to world prices in some markets (e.g., Kano) but not others (e.g., Lagos). Also, ad valorem tariffs are unlikely to explain the large observed price margins and have not varied with world prices in a way that should give rise to large price transmission parameters (rather, the opposite). This finding motivates further investigation into the structure (e.g., number of traders) of these markets, to ascertain the extent to which interpretation of market power as a key factor in rice and some maize markets is supported by that evidence. Informal consultations with Nigerian stakeholders, supported by limited data obtained from rice industry representatives, suggest that concentration ratios of marketing agents are high for rice importers from global markets, but lower for trade between commercial hubs and with neighboring countries.

CHAPTER 4. REMOTE SENSING DATA AND PRICE FORMATION IN NIGERIAN FOOD SECURITY CROP MARKETS

4.1 Introduction

Since the 2007-08 "food crisis", during which prices on global food markets and in many developing country food markets increased dramatically (Abbott and Borot de Battisti 2011), a variety of studies have analyzed how well prices are transmitted across markets, and to what degree other factors (e.g., weather, policy) besides prices in external markets explain price variation. Studies such as Baffes and Gardner (2003), Conforti (2004), and Minot (2011) found that markets in many Sub-Saharan African (SSA) countries are disconnected from global markets, but with variation across countries and crops. One implication of the findings that some countries and crops are imperfectly integrated with global markets is that other non-global price factors largely explain food price variation in many SSA country markets, especially over the short-run.

The results in Chapter 3 show that these findings broadly apply for Nigerian food markets. While Nigerian urban coarse grain markets are not well integrated with global markets, they are highly interconnected with markets in neighboring countries throughout West Africa. Urban rice markets appear linked closely to both world and neighbor country markets, although imported rice price variation was found to also be determined by market structural factors such as transactions costs or quality premiums that vary systematically with the world price and/or mark-ups by traders with market power. Within Nigeria, urban markets were found to be highly linked with each other, and to a greater degree than with rural markets for most crops. The observed relative isolation of Nigerian rural markets implies that other factors than external prices (e.g., weather, transactions costs) are more informative for explanation of price variation and changes in those markets.

Based on the findings in the literature and in the price transmission analysis in Chapter 3, the study in this chapter aims to analyze the importance of growing conditions as a factor behind explanation of price variation and changes in urban and/or rural Nigerian markets. The methods invoked here build on recent price formation analyses, such as those by Brown and Kshirsagar (2015) and Baffes, Kshirsagar, and Mitchell (2015), who utilized remote sensing data as a proxy for local expected agricultural production to explain food price changes. The specific focus of this chapter is to discern how and the degree to which these data capture growing conditions, and, thus, explain price variation. The economics literatures on spatial market equilibrium and parity bounds are called upon to justify the conjecture that harvest expectations, especially those formed in the lean season period immediately preceding harvest, based on information on local growing conditions and other factors, plausibly influence cross-market price relationships in Nigerian crop markets. The described market structural characteristics and existing market conditions (e.g., held stocks levels) are fundamental for explanation of the degree to which these expectations effects vary across crops and markets. The attributes of two alternative measures of harvest expectations, rainfall (as used in the price analysis by Aker 2010) and the NDVI, a commonly used proxy measure of changes in agricultural vegetation growth obtained by remote sensing, are compared in the context of Nigerian markets.

The empirical analysis investigates four existing issues in the current literature that pertain to the methods utilized by Brown and Kshirsagar (2015) and Baffes, Kshirsagar, and Mitchell (2015). The first issue is whether remote sensing data variables, such as the NDVI, which has been found to be correlated with agricultural vegetation (Rasmussen 1992), are valid proxies for expected production in price models. Brown and Kshirsagar (2015) and Baffes, Kshirsagar, and Mitchell (2015) do not consult the effects of actual production estimates on prices, but there is much historical (e.g., Working (1958)) and recent (e.g., Adjemian (2012)) evidence that such estimates influence markets. This apparent gap is filled in this study through inclusion of both NDVI and production variables in the econometric models, which are extensions of the models in Chapter 3. The degree to which production data explain price variation is, however, conditional on the quality of those data. The results in Chapter 2 showed that Nigerian agricultural production data are of broadly poor quality, which constrains the efforts to compare the relative importance of production estimates versus NDVI data in this Nigerian case.

The second issue relates to the relevant type of NDVI data variables to include in a price formation model. Brown and Kshirsagar (2015) and Baffes, Kshirsagar, and Mitchell (2015) used similarly constructed variables that identify specific NDVI anomaly periods as representative of periods of extreme vegetation fluctuations to explain price changes. In addition to this type of anomaly variable, NDVI first differences are also proposed in this study as another plausible variable for explanation of price changes. The NDVI first difference variable is argued to be especially relevant for crops that are primarily rainfall dependent and, thus, follow a clearer seasonal pattern (especially if the market is disconnected from other markets, implied by the estimated price transmission parameters).

The third issue of focus is with regard to identification of a proper spatial aggregation of NDVI data in the calculation of proxy variable values. Economic theory is helpful for investigation of this issue. The spatial equilibrium model of Ravallion (1986) is invoked to argue that socioeconomic characteristics and market connectivity are key to identification of proper market size. The scope of relevance for associated spatial NDVI data is, thus, a function of that market size. If a market is interconnected with many markets over a broad geographical area frame, then the growing conditions across that broader range are conjectured to be relatively more informative than growing conditions in one segment found within the enveloping area frame. Conversely, if a market is isolated, a narrow NDVI scope is called for.

The final issue that is explored is whether long-run price variation, in addition to short-run price changes, is plausibly explained by growing conditions changes over time. Economic theory on spatial equilibrium and on parity bounds is used to argue that expectations formed during years of expected extreme harvests, especially those formed in the lean season that immediately precedes harvest, can lead to changes in market outcomes, and, thus, also change relationships between prices in connected markets that can last for some months. The recent price formation studies of Brown and Kshirsagar (2015) and Baffes, Kshirsagar, and Mitchell (2015) only considered short-run effects, but we find econometric evidence that the long-run growing conditions effects on price relationships is stronger than short-run effects on individual price series variation in some cases.

The results of this study provide illustrative empirical evidence that is supportive of the conjectures proposed. In a broad sense, the results show that NDVI and production data are relatively more informative for explanation of short-run local price changes than rural or urban price changes that are aggregated across space. The NDVI data are also broadly most informative for explanation of short-run price changes for crops that are grown in the region of analysis (for Northern Nigeria these are millet, sorghum, maize, rice, and cowpeas). They are also at times helpful for explaining price variation for crops that are not widely produced but consumed in the region (cassava and yams), a finding which is plausibly due to substitution effects in consumption.

4.2 Theory of Harvest Expectation Effects on Cross-Market Price Relationships and Price Variability

The goal of this section is to provide economic theoretical reasons why remote sensing information, such as proxies for expected production, can help explain how relationships between prices in spatially disparate markets and price variation in individual markets may vary over time. It is conjectured that expectations of a harvest that is in either the upper or lower tails of the historical harvest distribution ("anomaly harvests"), formed in the period that immediately precedes harvest (commonly referred to as the "lean season"), change cross-market price relationships. The degree to which these expectations for "anomaly harvests" matter for explanation of cross-market price relationships is argued below to vary based on the relative interconnectedness of markets, the associated variation in transactions costs for facilitation of trade in markets with varying structures, and existing market conditions (e.g., held stocks levels).

4.2.1 Seasonality of crop prices

The markets of focus herein are Nigerian urban and rural markets for crops harvested once in a calendar or crop year (e.g., maize, millet, sorghum, and cowpeas), although there are plausible cross-market consumption substitution effects on prices of crops that may be harvested at multiple times during a crop or calendar year (e.g., cassava, yams, and to some degree rice). The prices of crops that have a single harvest in a calendar or crop year are described by Sahn and Delgado (1989) to have a typical seasonal pattern such that prices are lowest immediately after harvest when markets are saturated with newly harvested supplies, and then they rise throughout the year until the next harvest, accounting for the costs of storage. Under such a price path, the prices peak in the "lean season", which commonly occurs during the last portion of the growing season that immediately precedes harvest (Sahn and Delgado 1989).

Figure 4-1 below shows the 2010 urban prices for millet in Kano State[47], the home state of Dawanau Market, a key commercial hub and one of the largest grain markets in West Africa (Terpend 2006), and Damasak, Borno State, a small town located in Northwest Borno State near the Nigeria-Niger border. It is observed in figure 4-1 that both price series appear to have a seasonal pattern, but, of the two series, the price path for the Damasak, Borno millet prices better reflects the general seasonal pattern described by Sahn and Delgado (1989). There, prices rise from February through August (with a slight dip between April and May), then fall in September, presumably due to a realized harvest[48], and then rise again from October through December. The Kano State urban millet price series is relatively more stable for much of the year, until there is a decline in June 2010, a subsequent rise in September 2010, and then a fall again in October and November 2010, likely due to harvest realization.

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[47] These urban prices are from the Nigerian NBS and are aggregates of urban areas throughout Kano State, of which the city of Kano is the largest.

[48] The seasonal calendar provided by FEWS-NET shows that, generally, the harvest period for Northern Nigeria is from September through December, while the lean season is from July through September. This implies that the start of harvest and end of the lean season varies across crops and years. The website for the seasonal calendar is at this address: http://www.fews.net/west-africa/nigeria.

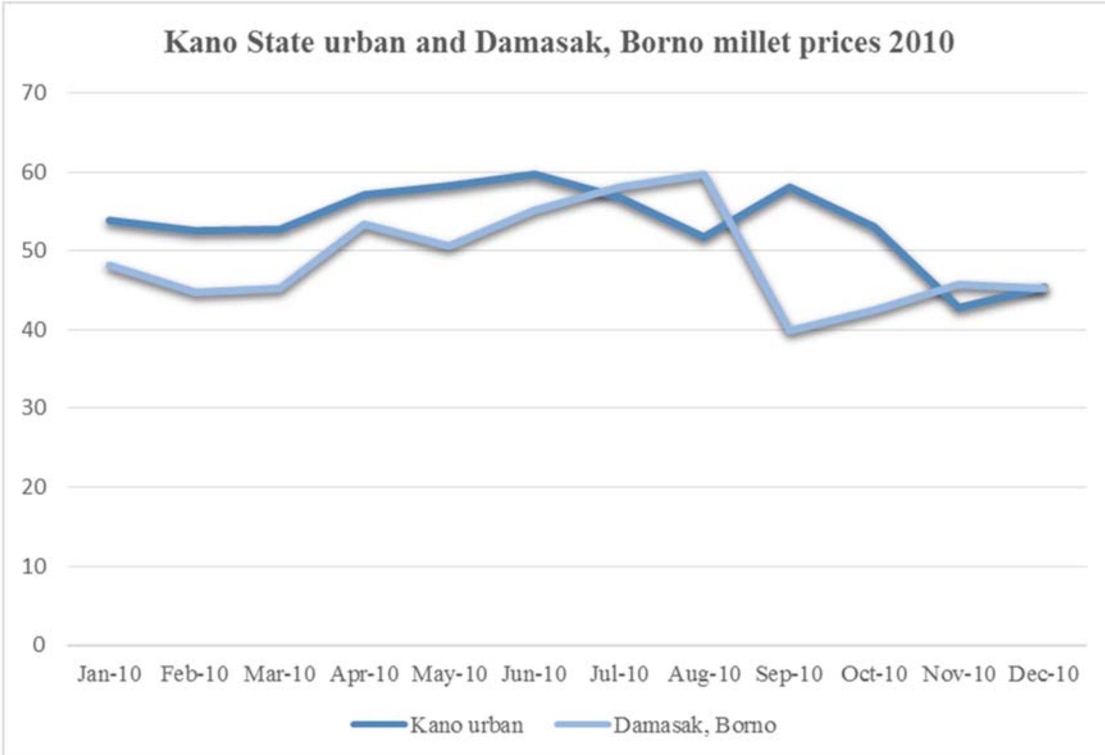

Figure 4-1: Kano State Urban and Damasak, Borno millet prices for 2010

Sources: Nigerian National Bureau of Statistics and the World Food Programme.

The observed difference in the degree to which the Kano State urban and Damasak, Borno millet prices display a seasonal pattern in prices relates to the individual structures of these markets. The price transmission results in Chapter 3 showed that, for coarse grains, the urban markets in Nigeria are highly interconnected with other urban markets in Nigeria and markets in neighboring countries. These price transmission results also showed that the Borno State urban and rural markets for coarse grains (and cassava and yams) are relatively disconnected. Thus, prices in urban markets in Kano State are relatively more determined by prices in connected markets than those in Damasak, Borno, and those in Damasak, Borno appear explained to a greater degree by seasonal variation in growing conditions and other local factors. Storage and storage costs also help explain the patterns in these data. Both series show rises in prices that begin in post-harvest periods and continue, although with intermittent fluctuations from the trend, up until the harvest period. This reflects that these prices account for storage costs over time, which are likely not equal since there is much greater commercial storage in Kano than Damasak.

The economic literature on spatial equilibrium and parity bounds provides key insights into understanding the relationships of prices in spatially disparate markets, and are called upon to justify the conjecture that harvest expectations plausibly influence the relationships between prices in linked markets and price variation in individual markets.

4.2.2 Spatial equilibrium and parity bounds

In the Ravallion (1986) spatial equilibrium context, the price in one market is influenced by the prices in all linked markets. If a market is a commercial hub, and so by definition has many market linkages, then the number of prices that inform the commercial hub price is higher than for an isolated market. Dawanau Market outside of Kano City in Kano State is an example of such a commercial hub. The prices in Dawanau Market are formed by a vast array of prices in markets throughout Nigeria and West Africa. At the other end of the interconnectedness spectrum is an isolated rural market, perhaps such as Damasak, Borno, which likely only has a few direct linkages to external markets.

These differences in interconnectedness of markets have important implications for the relative degree to which trade or other factors influence prices of agricultural crops. Trade costs are discussed within the "parity bounds" literature, in studies such as that by Baulch (1997), in an intuitive way that links the costs of implementing arbitrage transactions to prices in spatially disparate markets.

The parity bounds literature moves the discussion to focus on a single pair of markets. For illustration, suppose the reference market is a rural market in Nigeria and there is an external market that is an urban commercial hub market. The Ravallion (1986) spatial equilibrium framework indicates that the external market, thus, has relatively more market connections than the rural market. In the parity bounds literature (e.g., as in Baulch (1997)), the prices in the rural and external market, p and p^e, respectively, are equal under the law of one price (LOP), and are linked by the transactions costs of implementing arbitrage transactions[49]. Here we define the costs of transportation of a seasonally harvested crop from the external market to the rural market as s^i, and the analogous transport costs in the reverse direction as s^o. The Baulch (1997) arbitrage conditions, adapted for this relationship, for any period are:

1) Import parity bound, where trade flows from external to rural market if:

$$p \geq p^e + s^i;$$

2) Export parity bound, where trade flows from rural to external market if:

$$p + s^o \leq p^e; \text{ and,}$$

3) Within parity bounds, where no trade occurs if:

$$p^e - s^o < p < p^e + s^i.$$

The relative sizes of s^i and s^o vary across markets with different market structures, and the following discussion of how and why these transactions costs vary has key implications for whether other factors besides external prices (e.g., weather) would be expected to cause parity bounds to bind under certain circumstances. When the third arbitrage condition is relevant, which means prices are within the parity bounds, prices are determined by local conditions (e.g., weather) and not external prices. When either of the first two conditions hold with equality, prices are at parity and prices are determined by trade[50]. Hence, prices in external markets rather than local conditions explain prices when they achieve parity, even if arbitrage is slow.

4.2.2.1 Parity bounds and market structure

Transactions costs tend to be lower for facilitation of trade from connected markets to other connected markets than from connected markets to isolated markets or

[49] In an agricultural market setting, arbitrage is the buying and selling of agricultural commodities in spatially disparate markets to obtain profit that results from price differentials that exist after accounting for transportation costs. If a market is efficient, then all arbitrage profits available in the market are minimized and any profit that emerges is obtained instantaneously through trade actions by profit maximizing traders and/or farmers. These transactions cause the prices in the markets for which there was an observed differential to reach parity (Barrett 2001).

[50] It is important to note that the first and second arbitrage conditions are typically described in the LOP literature to hold with equality. Inequality relative to either the first or second conditions implies markets are segmented and the two prices are not in equilibrium. In the LOP literature, disequilibrium such as these represent an unrealized arbitrage opportunity, which would be captured instantaneously by profit maximizing traders and/or famers (Barrett and Li 2002). Our price transmission results in Chapter 3 and in the results section of this chapter imply that prices in the examined markets eventually achieve equilibrium in the long-run (i.e., they are cointegrated), but the achievement of equilibrium is not instantaneous.

between isolated markets. This is because there is commonly relatively poor infrastructure in isolated rural markets relative to urban commercial hubs (Porteous 2015)[51]. Also, the degree of competitiveness of markets is commonly lower in smaller markets, such that there may be oligopolistic or monopolistic markets that emerge because of the existence of economies of scale in bulk commodity transportation technologies that are only obtainable in larger markets (Barrett 1996). The degree of market competition can also change over time, and even within the course of a crop year. This change in market structure could occur because sellers run out of marketable supplies over the course of a crop year, and only those with relatively large initial stocks remain, and have the potential to obtain excess rents by the end of the crop year (Sarkar 1993). These observations imply that relatively more connected markets have much tighter parity bounds than isolated markets (Barrett and Li 2002). The tighter parity bounds of connected markets means that, assuming that arbitrage is implemented efficiently, these markets are more likely to be at the parity bounds, and, hence, implementing cross-market trade than are relatively isolated markets. These observations in the Nigerian context imply that Dawanau Market would have much tighter parity bounds than a more isolated market like Damasak, Borno, consistent with figure 4-1.

4.2.2.2 Timing aspects of parity bounds

The seasonal nature of agricultural marketing means that markets can move from one regime of trade or non-trade, as defined in the parity bounds arbitrage conditions, to another intermittently within a crop year (Timmer 1974). In such a situation, trade can reverse directions or be stopped such that markets become disconnected. This state of discontinuous and/or inconsistent trade flows over time appears to fit the stylized facts of Northern Nigerian cereals markets. Delgado (1986) observed that relatively much more trader facilitated transactions across spatially disparate markets occurred during the lean season than in the period that immediately followed harvest when local markets were more saturated with harvested supplies.

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[51] On the ground observations showed that this stylized fact generally applies for Nigerian markets.

In the anticipatory price model of Working (1958), expectations of the upcoming harvest are initially made in the growing season after planting, and then are continually updated until harvest (or until the first official estimates of the harvest size are released, which could be some months after harvest for most farmers)[52]. The formation of expectations causes farmers and traders to implement market activities (buy, sell, trade, or store) based on expected harvest size, which influences current prices (Goodwin and Schroeder 1991).

The period that immediately precedes harvest, is thus, viewed to be one in which it is most likely that parity bounds regimes, and thus trade flows and market connections, adjust, which is consistent with the situation of intermittent regime changes proposed by Timmer (1974). One factor that can move price relationships across parity bound regimes is policy. If policymakers are interested, for example, in stabilizing prices, then they may implement market activities that change transactions costs, prices, or both, and thus, alter existing trade flows at certain times (Timmer 1974). Additionally, if the information on expected harvest, which farmers and traders use to implement their marketing actions is poor, then consumers may consume too little and farmers or traders store too much, or vice versa, which also influences the seasonal pattern of prices (Hayami and Peterson 1972). Imperfect information, therefore, can also lead to movements in prices, and thus, plausibly change price relationships.

Under a similar logic, it is proposed here that expectations of extreme harvest events can also cause parity bounds conditions, and thus, price relationships, to change over time. To expound on this conjecture in more detail, the process in which expectations on the future are formed during the growing season, and the market impacts that result from actions implemented based on those expectations, are described in the context of extreme events. Figures 4-2 and 4-3 below each show a representative calendar year price path for a seasonally planted crop with the period from the start of the growing season to harvest highlighted. In each figure, the initial rural price is rising as it enters the growing season, which reflects accrued storage costs over time. There is an import parity

[52] In the case of the U.S., actual harvest estimates are released in the December WASDE report, which is some months after harvest typically ends in most regions of the U.S. (USDA-NASS 1997). Forecasts and updates for these final estimates are provided earlier, however.

bound above the base rural price, and no trade initially. The difference between the external price and rural price, which is the amount the rural price needs to rise before reaching the import parity bound, is equal to the costs of trade from the external to rural market (s^i). There is also an export parity bound below the base rural price, which reflects the costs of trade from the rural to the urban market (s^o). Since rural infrastructure is poorer than urban infrastructure in many African countries (Porteous 2015), it is portrayed in figures 4-2 and 4-3 that $s^o$is greater than s^i. The degree to which either the import or export parity bound is reached is thus a function of the distributions of the rural price, external price, and transactions costs.

Figure 4-2 below shows the case in which there is a poor expected harvest that is in the lower tail of the historical harvest distribution and a binding import parity bound. It is proposed in figure 4-2 that there is a point in time during the lean season that precedes harvest at which the harvest size expectation is formed (there could in reality be multiple updates leading up to harvest). In the scenario in figure 4-2, it is at this harvest expectation formation point at which market actions are implemented based on these expectations. The case of an extremely poor harvest plausibly leads to an increase in the demand for stocks, portrayed in Wright and Cafiero (2011) as an outward shift in the demand curve, which increases the price at each quantity demanded.

There are three situations that could occur as portrayed in figure 4-2 conditional on whether arbitrage is efficient, not implemented at all, or is imperfect. If arbitrage is implemented efficiently, which in this poor harvest case means that imports flow from the external to rural market, then after the extremely poor crop expectation is formed, the rural price rises to the point where the import parity bound is binding and it becomes equal with the external price. If arbitrage is not implemented, and thus, the import parity bound is non-binding, then the rural price is higher than both its initial level and that in the external market. If there is slow, imperfect arbitrage, then the price rises above the parity bound, but due to the eventual implementation of arbitrage, the price level does not reach as high as it would be in the absence of the eventual arbitrage (or even the existence of the potential for arbitrage).

The solid lines in figure 4-2 signify the price path under the assumption that efficient arbitrage is relevant. In this path, the rural price rises as storage costs are accrued until the harvest size expectation is formed, and then jumps to be equal to the external price since an extremely poor harvest was expected and arbitrage from the external market occurred. This jump to parity with the external price means that the prices were disconnected until the extremely poor harvest expectation was formed, but then connected afterward. Since the point at which the expectation of harvest is formed could be months in advance of harvest, the rural and urban prices could be relatively better linked under this case of an extreme harvest for an extended period, conditional on other market conditions.

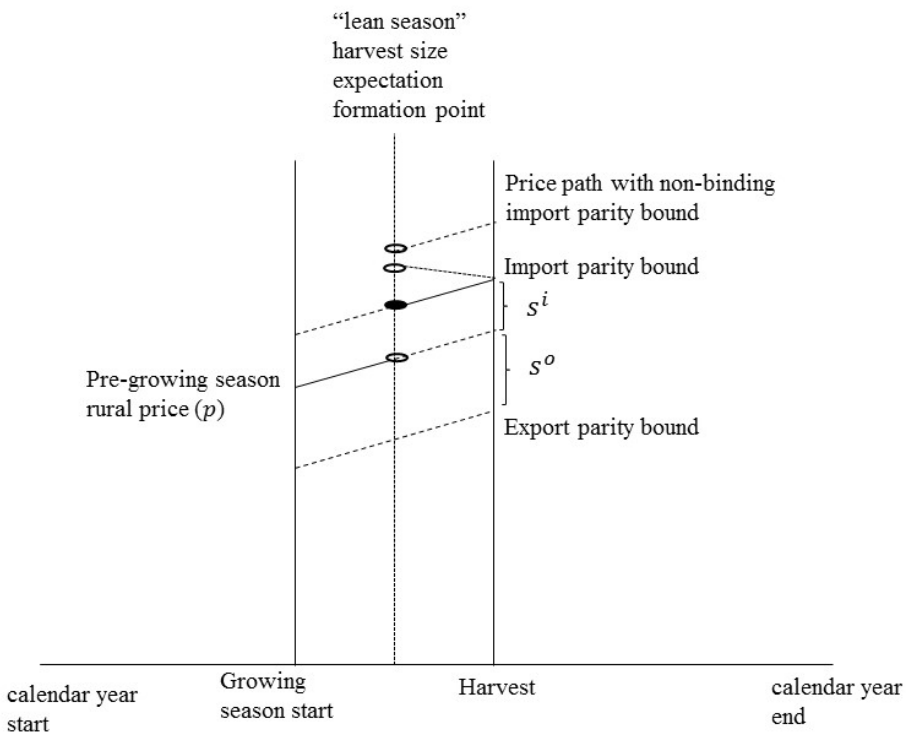

Figure 4-2: Representative calendar year for seasonal crop with a poor expected harvest and binding import parity bound

Figure 4-3 maintains the same main features as figure 4-2, but displays the alternative scenario in which the expected harvest is an extremely good rather than a poor one. Under this large expected harvest scenario, in which the harvest is in the upper tail of the distribution of historical harvests, there are three alternative price paths. If the export parity bound is non-binding due to arbitrage not being implemented efficiently, then the rural price could fall below its initial level and that of the external price. In the second scenario, reflected as the price path with the solid lines, it is assumed that arbitrage is implemented efficiently. In this second price path, the price falls to the point where exports to the external market occur and the rural and external prices are at parity. The decline in the rural market price could result from a dumping of held stocks due to expectations of large harvested supplies. If export parity is binding, then some of these released stocks flow from the rural market to the external market, linking the prices in these markets to a greater degree than before the expectations were formed. In the third case, if there is slow, imperfect arbitrage, then the price declines below the export parity bound, but not quite to the level with a non-binding export parity bound, and moves toward the parity bound due to the eventual occurrence of arbitrage (or even the possibility that arbitrage could occur). If the expectations of an extremely good harvest are formed months in advance of harvest, then the increased price correspondence between the rural and urban market could persist for some months.

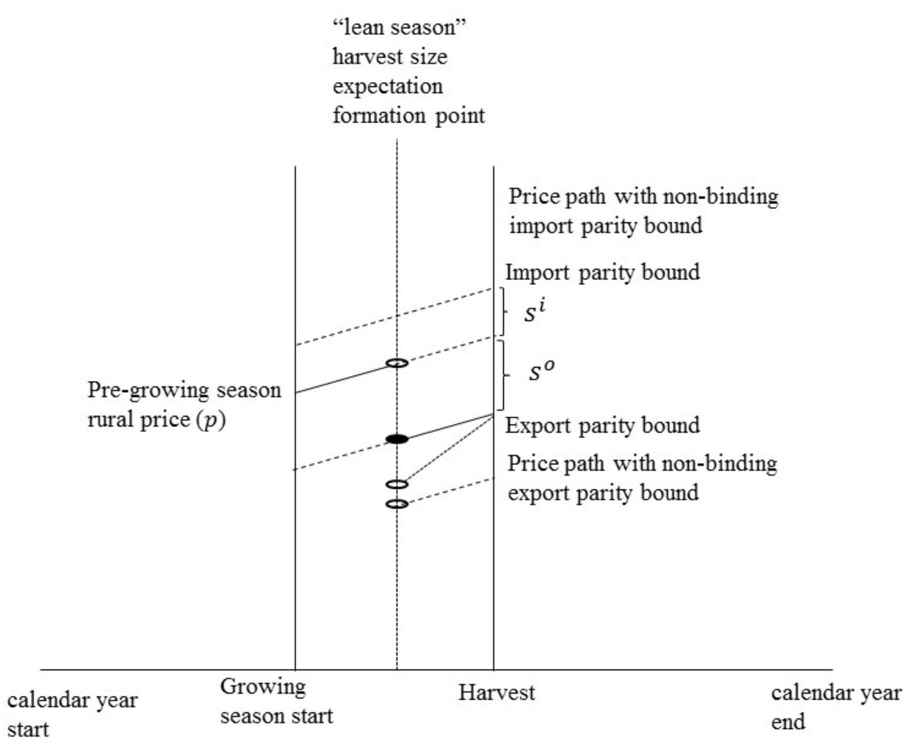

Figure 4-3: Representative calendar year for seasonal crop with a good expected harvest and binding export parity bound

While figures 4-2 and 4-3 emphasize that there may be longer run effects on price relationships due to adjustments in expectations of harvest under extreme growing conditions, the changes may intermittently reverse directions, and are dependent on the sizes of the expected effects and transactions costs. Thus, they may not reach either parity bound. This logic implies that expectations for harvest can also have effects on short-run prices that may only influence the rural price path and not the long-run relationship between the rural and external market prices. Under the anticipatory price model of Working (1958), expectations are continually updated, so prices plausibly can fluctuate within the parity bounds and/or move into and out of the parity bounds as new information is obtained over the course of the growing season. The timeliness and quality of the information on growing season conditions is, therefore, crucial for understanding the short-run effects of growing conditions changes on prices. The above discussion described how more interconnected markets are more tightly bounded by parity bounds, however, and so short-run movements within the parity bounds and/or movements into and then out of the parity bounds in the short-run are relatively more plausible for disconnected rural markets than for highly connected urban markets. In the disconnected market case, the magnitudes of the short-run price changes, as argued by Wright and Cafiero (2011), are linked to the sizes of initial stocks. If initial stocks levels are low, then the price changes that result from a downward shift in expected supply are larger than they would be under normal stocks since market demand is relatively more inelastic under low than normal stocks.

The cases represented in figures 4-2 and 4-3 provide some insights into the seasonal nature of agricultural marketing in developing country rural markets, which are helpful for understanding price transmission model results of such markets. The initial state in both figures 4-2 and 4-3 was one of temporarily segmented markets[53]. In the unlikely case that external market prices are determined by the same local condition factors as the rural market (e.g., correlated weather patterns with similar geophysical characteristics), then these prices would co-move even in the absence of trade (Barrett

[53] Barrett and Li (2002) describe two types of segmented markets: 1) those in equilibrium, in which trade does not occur because it is not profitable to do so; and, 2) those in disequilibrium, in which trade does not occur, but there is potential for profit, implying existence of market imperfections.

and Li 2002). In this case, and in the case in which prices are always at one of the parity bounds, the estimated price transmission parameters of an econometric model that represented the relationship between these prices would be equal to 1 (which implies a one-for-one price correspondence). In the case of temporarily segmented markets, due to high transactions costs, imperfect competition, or other distortions, and in which the external market price is influenced by different conditions (and other market prices) than the rural price, the estimated price transmission parameter in an econometric model that represents the relationship between these prices would be less than 1. In Chapter 3, estimated price transmission parameters with magnitudes well less than 1 were commonly observed, especially for the urban-to-rural price transmission models. These results imply that these markets are often segmented, which could only be relevant in certain seasonal situations that arise intermittently under some market conditions.

While this discussion of seasonality, parity bounds, and price transmission is informative for formation of expectations for results from the price transmission models that account for some seasonal information that follow in the next section, it is quite limited in its generality. There are many plausible scenarios in which the price relationships can adjust due to seasonal factors in parts of the crop year outside of the growing season. One key period in which it has been commonly observed that market connectivity changes is during the period that immediately follows harvest. Relationships between rural and external prices could be different in the post-harvest period, when prices are typically at their seasonal low, than in other periods because farmers are eager to sell if sufficient storage facilities do not exist, or because farmers are liquidity constrained due to credit market imperfections (Stephens and Barrett 2011). It is, thus, more plausibly the case that price relationships fluctuate at multiple periods throughout a season, conditional on growing conditions and other factors such as the magnitudes of currently held stocks.

4.3 Empirical Framework

Based on these theoretical observations and conjectures, an empirical model is needed that is representative of a long-run equilibrium relationship between prices that can change over time under certain conditions, and accommodates individual price series that exhibit seasonality that may vary based on production shocks. The two-stage cointegration framework of Engle and Granger (1987) is well-suited for analysis of long-run relationships of price levels under the potential for short-run shocks (Baffes and Gardner 2003). The following empirical model is, thus, a version of the Engle and Granger (1987) two-stage cointegration method that accommodates the potential for the cointegrating relationship to change under specific circumstances. Namely, the relationship between the rural and external prices is expected to be stronger during lean season periods in which there is an extreme expected harvest that is in the outer tails of the distribution of historical harvests.

4.3.1 Long-run levels models

To begin, it is assumed that parity bounds hold and trade occurs in at least enough of the observation periods required to establish a long-run equilibrium relationship between the rural and external prices. It is assumed that the first of the arbitrage conditions, such that trade moves from the external to rural market, is likely to occur most regularly, although all three could plausibly occur and to different degrees based on the crop, time of year, and characteristics of the markets being analyzed. If the first arbitrage condition is applicable and the import parity bound is binding, then the LOP relationship that exists is:

$$p = s^i + p^e. \tag{6}$$

The normalization of equation (6) is consistent with trade flows moving from the external market to rural markets.

While equation (6) is consistent with the more regular movement of trade flows from the external to the rural market, these markets could become disconnected or trade may be reversed intermittently. In such cases, the relationship between the rural and external prices change. Barrett (1996) argued that in order to comprehensively account for such parity bound regime changes in an empirical model, information on both transactions costs and trade flows is needed. While the data on trade flows are commonly unavailable[54], as is the case here, interpretation of coefficients on a regression of equation

[54] To the author's knowledge, only Barrett and Li (2002) have implemented a price analysis that included each of prices, transactions costs, and trade flow data.

(6) can provide insights into the relative degree to which rural and urban prices co-move or fluctuate independently over time.

The general form of equation (6) is consistent with the LOP literature. Ardeni (1989) argued that the LOP relationship in (6) means the rural price and external price are expected to move together in the long-run (i.e., be cointegrated as defined by Engle and Granger 1987), and any movement away from equilibrium would be resolved through spatial arbitrage. This implies that the rural and external prices are expected to be cointegrated if there are enough instances in which the parity bounds are binding such that trade occurs.

A linear levels cointegration model consistent with equation (6) is, thus, proposed, such that in each period t:

$$p_t = \alpha + \beta p_t^e + u_t, \tag{7}$$

where α is the intercept term that accounts for transactions costs that do not vary systematically with the external price, β is the price transmission parameter that measures the degree of price correspondence between the external and rural markets, and u_t is the random error. If the parity bounds bind in enough periods, then the prices correspond highly with each other and the estimate of β in a regression ($\hat{\beta}$) is higher than would be the case if the parity bounds do not bind very often. If LOP holds over the long-run, the parity bounds commonly bind, or other factors cause the prices to vary in a similar manner over time (e.g., correlated weather patterns), then $\hat{\beta} = 1$ (Baffes and Gardner 2003). If there are commonly occurring phenomena that cause the parity bounds to not hold (e.g., persistently high transactions costs or poor information), however, then the prices will move independently to some degree, LOP will not hold, and $\hat{\beta} < 1$.

The base long-run levels model in equation (7) is now expanded to account for the extreme harvest expectation phenomena discussed above in the context of figures 4-2 and 4-3. In such scenarios, there is a "lean season expectation of an anomaly harvest", in which an anomaly is defined as an expected harvest size that is in one of the tails of the historical production distribution. Such a "lean season expected harvest anomaly" effect is captured through expansion of equation (7) to include an indicator variables that represents the lean seasons for the years in which there are sizable expected downward anomaly, $I_t^{d,ls}$, or upward anomaly, $I_t^{u,ls}$, harvest sizes relative to the historical mean. To construct these indicator variables, it is necessary to identify the relevant period of the lean season in normal years, then identify the expected harvest anomaly periods, and, lastly, match these periods to isolate only the lean season months for the years when either an upward or downward expected harvest anomaly is observed.

Since there are theoretical reasons for expected harvest anomalies to plausibly influence the degree to which parity bounds bind for an extended period, and thus, change the degree to which the rural and external prices co-move, these lean season expected harvest anomaly indicator variables are introduced in equation (7') below as interaction terms with the external price. This yields:

$$p_t = \alpha + \beta p_t^e + \beta_d\left(p_t^e * I_t^{d,ls}\right) + \beta_u\left(p_t^e * I_t^{u,ls}\right) + v_t, \qquad (7')$$

where β_d is the parameter that measures the degree to which the lean season price correspondence between the external and rural price is greater during scenarios of downward expected harvest anomalies than in normal periods; and, β_u is a parameter that measures the same, but for upward harvest anomalies. Equations (7) and (7') represent alternative first stage levels models of the Engle and Granger (1987) two-stage cointegration estimation method.

Statistically significantly different than zero "lean season anomaly" variable parameters ($\widehat{\beta_d}$ or $\widehat{\beta_u} \neq 0$) imply that the general cointegration parameter that measures the long-run rural and external price relationship in equation (7) is non-constant over time. Gregory and Hansen (1996) found that the existence of non-constant cointegration parameters is consistent with cointegration among variables that have a long-run equilibrium relationship. They provided evidence that this can be the case through estimation of empirical models that include indicator variables to demarcate the periods of relationship differences, as is done in equation (7')[55].

[55] Note that Gregory and Hansen (1996) included the indicator variable such that it adjusted both the intercept and slope parameters of the cointegration regression equation. Here it is only tested if the price correspondence is either higher in the extreme expected harvest cases, because it is more consistent with the theory outlined above.

4.3.2 Short-run error correction mechanism models

The theoretical discussion above also provided insights into the potential for short-run effects on prices that occur each growing season as market participants adjust expectations for the upcoming harvest over time. These short-run effects can be accounted for, within the context of the long-run equilibrium relationship established in equations (7) and (7'), in the second stage error correction mechanism (ECM) model of the Engle and Granger (1987) two-stage cointegration method. In a manner similar to that proposed by Banerjee et al. (1986), and supposing that the lean season anomaly effects are relevant for the levels of prices, the base ECM model associated with equation (7') is:

$$\Delta p_t = -\gamma \hat{v}_{t-1} + \delta \Delta p_t^e + e_t, \tag{8}$$

where γ is the error correction parameter, which measures the degree to which a disequilibrium between the rural and external price is lessened after one month, $\hat{v}_{t-1}$ are the lagged residuals from estimation of the levels models in equation (7')[56], δ is the short-run responsiveness parameter of rural price changes to changes in the external price, and e_t is a random error.

The previous section described how information on expected production could be useful for explanation of price changes over time, but most plausibly applies for markets that are more isolated and so do not have prices that are persistently bound by the external prices. The case of a typical crop year was portrayed above as evolving such that price adjustments are plausibly observed intermittently throughout the growing season as market participants adjust their expectations for upcoming harvest and implement market activities accordingly. These changes may be substantial in some cases, dependent on market conditions such as stocks availability and the quality of information. Price changes are also expected in years when anomalous harvest quantities are expected, although information on local conditions would be needed to discern whether price changes would be statistically significantly higher or lower in expected anomalous production years versus normal years.

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[56] In the case that the interaction terms in equation (7') are not statistically significantly different than zero, which implies that the cointegration parameter is constant over time, the residuals from the base levels model in equation (7) would be included in the ECM model.

The plausibility of these growing conditions effects on short-run price changes leads to expansion of equation (8) to include both changes in expected production, Δy_t, and indicator variables that identify downward expected harvest anomaly periods, $I_t^{d,gs}$, or upward expected harvest anomaly periods, $I_t^{u,gs}$. Note that the short-run indicator anomaly variables are slightly different than those in the levels models. The anomaly variables earlier indicated the lean season months for years with extreme expected production observations, while these are the actual monthly indicators for those extreme periods, which are observed intermittently.

The expansion of equation (8) to include these effects results in ECM models (8') and (8''):

$$\Delta p_t = -\gamma \hat{v}_{t-1} + \delta \Delta p_t^e + \theta \Delta y_t + e'_t, \tag{8'}$$

and,

$$\Delta p_t = -\gamma \hat{v}_{t-1} + \delta \Delta p_t^e + \theta_d I_t^{d,gs} + \theta_u I_t^{u,gs} + e''_t, \tag{8''}$$

where e'_t and e''_t are random errors, respectively. If the changes in expected production and expected harvest anomaly variables are both relevant, then equation (8) can be expanded to accommodate both potential effects. If the estimated parameters associated with the variables that represent the various changes in expected production throughout the growing season, $\hat{\theta}$, $\widehat{\theta_d}$, $\widehat{\theta_u}$, are statistically significantly different from zero, then it implies that changes in expected harvest due to growing conditions explain short-run changes in prices.

Inclusion of the indicator variables that represent anomalous adjustments to expected production during the growing season in an ECM model in equation (8'') is analogous to the methods implemented by Baffes, Kshirsagar, and Mitchell (2015) and Brown and Kshirsagar (2015), which both used monthly anomaly indicator variables (lagged in the case of Brown and Kshirsagar (2015)). The inclusion of the lean season expected harvest anomaly indicator variables in the levels model in equation (7'), and the changes in expected production in equation (8') are, therefore, expansions on their methods.

4.3.3 Econometric issues

The econometric issues that pertain to price transmission cointegration analyses, as described in section 3.3.3 of Chapter 3, are applicable to this framework as well. Unitary cointegration results in Chapter 3, Appendix 3C show that unitary cointegration rarely applies for the urban-to-rural price models. Since unitary cointegration assumes that only external price effects matter, these cases in which unitary cointegration is not found are those that are most relevant for this study that estimates the degree to which growing conditions matter for price transmission. Attention will be focused on the growing conditions related variables and the statistical significance of estimated long and short-run estimate price transmission parameters in models that account for these local conditions effects. Stationarity of the series was again tested with the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. Cointegration was also similarly tested through both stationarity tests of the residuals (both ADF and PP tests) in the levels models, and the statistical significance of the estimated ECM parameter ($\hat{\gamma}$) as proposed by Banerjee et al. (1986).

4.4 Data Used in Empirical Analysis

The relationship between expected harvest and prices is fundamental to the above theoretical and empirical models. Since expectations are often only observable through market outcomes that result from the implementation of transactions based on those expectations, it is necessary to identify plausible proxy variables for expected production. It is presumed that suitable proxy variables for expected production reflect well local growing conditions, and also capture the market size features of the above described spatial equilibrium theoretical framework. The attributes of two potential proxy variables for expected production, rainfall and NDVI, are now discussed in the context of Nigerian markets.

4.4.1 Relationship between agricultural production and remote sensing data

The above theoretical discussion made the case that expectations on production have important implications for prices in the short-run, and plausibly the long-run under some market conditions. There is an issue, however, with accounting for expected production in an empirical model, which arises from harvest occurring annually while expectations for that harvest are updated continuously.

In the U.S., the U.S. Department of Agriculture World Agricultural Outlook Board (WAOB) reports pre-harvest forecasts for agricultural area and yield for the main crops in the U.S. through their WASDE reports, which are initially released each year in May, with updates provided in June and July and a final post-harvest estimate reported the next December (Good and Irwin 2011). These reports and updates are a rich source of information on the market implications of growing conditions throughout the country for market participants, and the release of the reports have been found to have statistically significant impacts on prices (Adjemian 2012).

In developing countries such as Nigeria, production estimates for the current crop year are often not reported in a timely manner, and current growing season reports are not released in a systematic way that plausibly informs real-time market participant decisions (see Chapter 2 for details). In this context, therefore, the issue of accounting for expected production in empirical price models has been resolved in the existing literature through inclusion of proxy variables that have a strong positive correlation with agricultural production: mainly, rainfall data and remote sensing data such as NDVI.

Rainfall has been found to have a positive relationship with agricultural yield, but the degree to which yield variation is explained by changes in rainfall varies across crops and depends on the timing of the rainfall. Upward changes in rainfall are more positively correlated with higher yield for rice than maize and sorghum, for example (Lobell and Field 2007). The NDVI is a general measure of "greenness" or vegetation associated with a parcel of land at any given time as captured in a satellite picture, and the data from pictures at consecutive intervals can be utilized to observe changes in vegetation growth over time (Peters et al. 2002). NDVI data have been found to be positively correlated with general changes in biomass (Tucker et al. (1985) and Prince (1991)), as well as with specific agricultural vegetation (Rasmussen 1992)[57].

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[57] Chapter 2, Section 2.3.2 has a more detailed discussion on the relationship between NDVI data and agricultural production.

There are temporal, spatial, and practical issues that are relevant for use of either rainfall or remote sensing data in a price formation model. The temporal aspect is arguably the least limiting of these issues. Presumably, if weather stations that gather rainfall data were in existence and operational during the desired operation period, then obtaining rainfall data for crucial crop year periods such as the growing season is not problematic. NDVI data are available from 1960 on the National Aeronautics and Space Administration (NASA) Reverb website[58], and at either 16-day or monthly intervals.

The spatial issue is perhaps more limiting, and has important implications for use of these data. In the spatial economic model outline above, the market size was identified as important with regard to price formation. In this context, matching rainfall or NDVI data to the relevant area of observation is crucial. Rainfall data may, therefore, be relatively more problematic than NDVI in this regard because the rainfall data are gathered at weather stations that may not be located in the relevant areas associated with the markets of observation. In a model that sought to explain weather effects on agricultural prices in Niger, for example, Aker (2010) used rainfall data from a limited number of weather stations in different locations and matched markets to the station that was most nearby. In such a context, the degree to which rainfall or other weather variables matter in explaining aggregate yield variation is dependent on the degree to which other non-weather local conditions (e.g., soil quality) are correlated in an observation area (Woodard and Garcia 2008). The spatial issue may be somewhat less problematic for NDVI data, because, as a general measure of greenness, it captures not only rainfall variation over space, but also fluctuations in other growing conditions variables that may impact yield (e.g., air temperature). A key issue with use of NDVI data for assessment of fluctuations in agricultural yield across space then is the ability to demarcate agricultural from non-agricultural vegetation. The strategy in this paper was to use a "cropland mask" provided by the African Soil Information Service (AfSIS), which was used to remove urban and heavily wooded areas from the observation frame.

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[58] The address for the NASA Reverb website is: http://reverb.echo.nasa.gov/reverb/#utf8=%E2%9C%93&spatial_map=satellite&spatial_type=rectangle.

The degree to which practical issues are limiting for rainfall or NDVI data likely varies across countries and areas of observation. The NDVI data are available globally from the NASA website, and tools are also available online for conversion for use in data mapping programs such as ArcMap. This ability to download historical data online and then use economic theory to isolate the relevant areas makes NDVI plausibly more user friendly than rainfall data in most developing country settings. The above observations that NDVI data also have some desirable temporal and spatial characteristics in terms of measurement of changes in agricultural vegetation over time led to the identification of NDVI data as the most reasonable proxy for agricultural production in the study areas in Nigeria. NDVI data were used in the recent studies by Baffes, Kshirsagar, and Mitchell (2015) and Brown and Kshirsagar (2015) that also sought to explain movements in developing country agricultural prices. The discussion in Section 2.3.3 of Chapter 2 highlights, however, how much research remains with regard to determination of the relevant areas in the context of agricultural markets. A contribution in this paper is to rely upon economic theory to help determine multiple potentially relevant area sizes (i.e., “scopes”) upon which to aggregate NDVI data, and use each measure in the empirical models to compare how well the results reflect expectations based on that theory.

While NDVI data are viewed to be a plausible proxy for expected agricultural production, the rational expectations framework implies that the actual estimates of production would also be relevant for explanation of prices. Both NDVI and agricultural production data are, therefore, utilized in the present analysis.

Recall that in Chapter 2, however, Nigerian production data were generally found to have low (or negative) correlations with NDVI, and unexpectedly positive correlations with prices. The finding of the expected negative correlation between NDVI and prices, however, led to the conclusion that agricultural production estimates may not reflect well on the ground conditions in most cases, but the NDVI data do better. It is, therefore, expected that the NDVI variables will be broadly more informative in explaining the variation in prices than are the Nigerian production data, but most especially for the crops for which there was least confidence in the quality of production estimates. Our subsequent results will confirm this.

NDVI data are most useful when compared to an expected historical pattern of agricultural production. NDVI observations can be obtained at monthly intervals, while production estimates are generally annual. The potential for different time intervals for NDVI observations and production estimates, thus, mean that there are a number of ways to compare NDVI observations to expected production. The NDVI observations that are most informative for the historical pattern of production may be either anomaly periods that diverge substantially from the historical mean or first differences that measure each monthly change. It is plausibly the case that these different NDVI measures would correspond relatively well with prices of crops with varying degrees of seasonal price patterns and other market structure characteristics. The merits of these two measures of NDVI are evaluated in the context of their relative goodness-of-fit in the subsequent empirical models, and how those goodness-of-fit statistics compare to the models with agricultural production.

4.4.2 Construction of variables from remote sensing and production data

In order to calculate "anomaly" periods across crop years for the various regions of observation described below, the NDVI mean was first calculated for every month in a year. The individual monthly observations over the relevant observation period were then compared to the mean associated with each month. If the difference between the monthly observation and the mean for the month was greater or less than 5% of the mean, then it was identified as either an upward or downward anomaly month, respectively[59].

Individual indicator variables were created for each of the observation regions (listed below) to represent downward and upward NDVI anomalies, respectively. Only months in the growing season period as defined in the FEWS-NET "seasonal calendar", which are April through October, were considered for construction of NDVI anomaly variables. The downward NDVI anomaly variable takes a value of 1 for any month during the growing season for which there was an NDVI value that was greater than 5% below the mean value for that month, and a 0 for all other months. The upward NDVI

[59] Baffes, Kshirsagar, and Mitchell (2015) used an anomaly threshold of 10% for their analysis of maize prices in Tanzania. The 10% threshold was seldom breached for the markets analyzed here, which suggests that Northern Nigeria has less variable seasonal vegetation than Tanzania.

anomaly variable had a value of 1 for the months for which the NDVI value in a growing season month was 5% above the mean value for that month, and a 0 for all other months.

The lean season was determined using the FEWS-NET "seasonal calendar" for Northern Nigeria. The lean season for Northern Nigeria in a normal crop year is described to include the months of July, August, and September, but potentially could extend through October in some areas and in some years. A "lean season" indicator variable was, thus, constructed such that it takes a value of 1 for July, August, and September, and a 0 for all other months for each year during the observation period.

The "lean season expected harvest anomaly" indicator variables were created for each region such that they represent both region specific variables that identify the years in which there was either a "lean season downward anomaly" or a "lean season upward anomaly." Each of the lean season expected harvest anomaly indicator variables, thus, only identify the lean season months in years when there were expected harvest anomalies during the growing season. For these "lean season expected harvest anomaly" indicator variables, it is only possible to have a value 1 for the lean season months of July, August, and September. To create these variables, the downward and upward growing season NDVI anomaly variables were matched with the lean season indicator variable. If there was one or more downward anomaly periods in a given growing season, then the downward anomaly lean season indicator variable has a value of 1 for July, August, and September for that year, and a 0 for the other months in that year. Analogously, for the upward anomaly lean season indicator variable, if there was an upward anomaly or more in the growing season of a given year, then the lean season months of July, August, and September receive a value of 1, while all other months for that year have a value 0[60].

First differenced NDVI data variables were also created at the Northern Nigeria, state, and local scopes. These NDVI first difference variables and the first differenced

[60] In a few rare cases there were both downward and upward anomalies in one growing season. In that case, the direction (downward or upward) for which there were more anomalies determined the type of anomaly year it was for purposes of the lean season expected harvest anomaly variable construction. In even rarer cases there was an equal number of upward and downward anomalies in a growing season. In that case the anomaly direction that was closer to the lean season determined the type of anomaly year.

national and state level production estimate variables represent the short-run changes in expected production.

Prior to discussion of the results, it is worthwhile to describe how the construction of the above growing conditions related variables influences interpretation of the regression estimates. The coefficients on the NDVI first difference variables are somewhat difficult to interpret, and are clouded by the anomaly period effects. This is because NDVI data are cyclical, and so are the prices for some crops and in some markets (e.g., those crops grown in isolated, rainfall dependent areas). If those cycles align well with each other in normal years, then a positive relationship may be found such that NDVI and prices are both rising in the growing season as vegetation increases and as prices rise accounting for storage costs. This is only applicable in the rare case in which there are no expected harvest anomalies or significant demand changes, however, and implies that NDVI is a proxy to capture seasonality In general, annual measures of growing season NDVI averages are expected to be negatively correlated with associated harvest period prices, as found in Chapter 2. The expected NDVI anomaly variable relationships with prices are clearer since these variables identify specific periods in which the average cyclicality in NDVI is disrupted. In those periods, with demand and other supply effects held constant, upward (downward) NDVI anomalies are expected to be associated with downward (upward) changes in prices. The production first difference variables are annual, and so reflect inter-annual adjustments in production in a similar manner to production levels. Thus, with demand and other supply effects held constant, a positive (negative) change in production is expected to be associated with a negative (positive) change in prices. Hence, there is a negative relationship between production and prices.

4.4.3 Study area and types of data

Urban and rural prices of three states in Northern Nigeria -- Kano, Katsina, and Borno -- and prices for local towns in Katsina and Borno states are analyzed. These states have some similarities with regard to climate and geophysical characteristics, but also offer some contrasts. While each state is in Northern Nigeria, Kano and Katsina states are located in the extended Niger River Basin to a larger degree than is Borno State. Only the very southern portion of Borno State is located within the extended Niger River Basin. Goulden and Few (2011) include a map[61] that portrays the Niger River and its main confluence rivers. These include the Sokoto River, which flows north off the portion of the Niger River in Northwest Nigeria and then east into Katsina State and toward Kano State, and the Benue River, which flows to the northeast off the portion of the Niger River located in Central Nigeria and extends to the southern portion of Borno State. The majority of Katsina State, therefore, is located within the broader Sokoto River Basin, while only a relatively small portion of Borno State has river basin characteristics. Kano State borders a large area within the Sokoto River Basin, and its socioeconomic characteristics as a commercial hub (described below) mean it likely sources much agricultural production from markets in the river basin areas. The implication of the geophysical characteristic differences in these state is that Katsina State plausibly has much more widespread irrigation opportunities than Borno State, and so agricultural production is relatively less dependent on rainfall in Katsina than in Borno State. Presumably large deviations from the norm in rainfall would not only affect intra-year plant growth, but also river flows, so the years of upward or downward anomalies would be expected to affect agricultural production in all of the observation states.

The few rural towns included in the analysis are: Damasak, Borno; Daura, Katsina; and, Jibia, Katsina. These were chosen because they were the 3 of only 5 local markets for which the World Food Programme currently gathers data in Nigeria (more details below). These towns were chosen because they are dispersed spatially across regions with different geophysical characteristics, which allows for comparison of growing conditions effects in markets with varying attributes[62]. Figure 4-4 below is a map that displays Katsina, Kano, and Borno states; the local government areas within which Damasak, Daura, and Jibia cities are located, which are Mobbar, Daura, and Jibia, respectively; and, a representation of the river networks throughout the country as estimated in the DIVA-GIS database.

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[61] The map is on p. 14 in Goulden and Few (2011).

[62] The other 2 markets are in Jigawa and Sokoto states. These were not included in the analysis because these states have similar geophysical attributes to Katsina State, and so similar growing conditions effects are likely to apply for those states as are found for Jibia and Daura in Katsina State.

The data included in the empirical analysis are: prices in the markets that are to be explained, prices in external markets, remote sensing NDVI measures, and production estimates. All markets in the analysis are located in Northern Nigeria, because of observations in Chapter 2 that showed that fluctuations in vegetation as measured by NDVI are larger in Northern than Southern Nigeria. Growing conditions effects are, therefore, expected to be relatively more important for explanation of price formation in the north than the south. Multiple states in Northern Nigeria are included to allow for observation of the differential effects of growing conditions changes on prices in areas with different geophysical characteristics and market structures. The same crops included in the analyses in Chapters 2 and 3 are analyzed here as well, including: maize, millet, sorghum, imported rice, local rice, cassava, yams, and cowpeas.

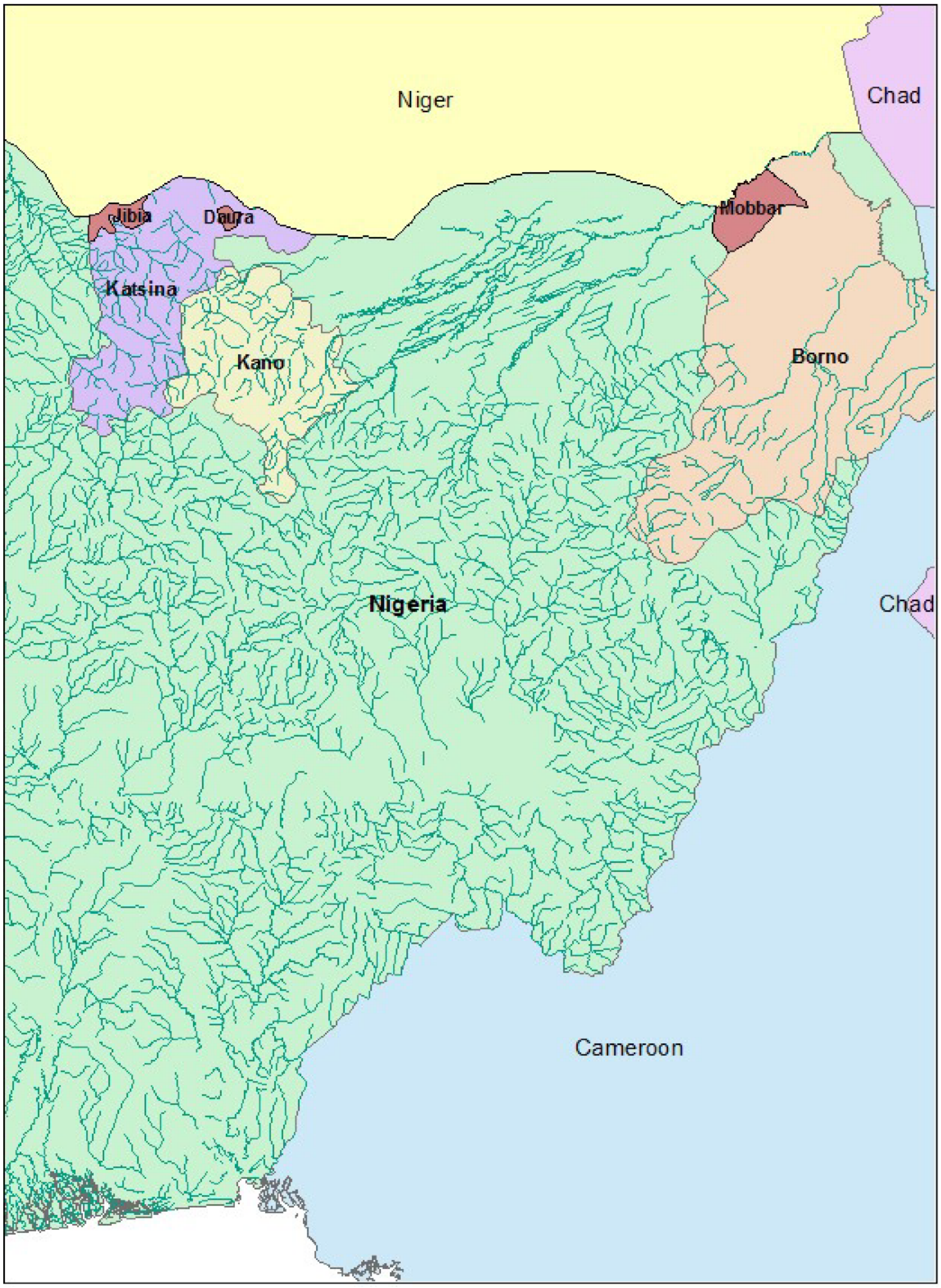

Figure 4-4: Map of Katsina, Kano, and Borno States with local government areas and rivers highlighted

Note: Map was created with data from DIVA-GIS database. The towns of Damasak, Daura, and Jibia are located in Mobbar, Daura, and Jibia local government areas, respectively.
Source: adapted from Goulden and Few (2011).

4.4.4 Urban model data

The urban set of models were implemented for Kano, Katsina, and Borno states. The urban prices used in the analysis are from the Nigerian National Bureau of Statistics (NBS), and are for the period of January 2001 to December 2010. The external prices for each crop and state are either "world" prices from global markets, or neighbor country prices, and are listed in appendix 4A of this chapter. These data are from the World Bank, GIEWS, and the World Food Programme. Where necessary, these prices were adjusted to Nigerian Naira per kilogram by exchange rates, which were obtained from the International Financial Statistics Database of the International Monetary Fund, the Federal Reserve Economic Database (FRED) of the St. Louis Federal Reserve, and the Bank of Ghana. To determine which external price to use in the analysis, the adjusted-R^2 values from estimation of base models in the form of equation (7) were compared. The price series with the highest adjusted-R^2 of all potential world and neighbor country prices was included in the analysis[63]. Tables with the price series included in this analysis and summary statistics for the Katsina State urban prices are in Chapter 4, Appendix 4A. Summary statistics for the Kano and Borno state urban prices are in Chapter 3, Appendix 3B.

Two scopes of NDVI data were included in the urban set. These are those associated with cropland area of Northern Nigeria and cropland in each respective state[64]. The NDVI value obtained for each month for Northern Nigeria cropland is, thus, the average NDVI value across all satellite pixels in the entire Northern Nigeria region cropland area. The NDVI value at the state level is the average value NDVI value across satellite pixels associated with the cropland area within each respective state border for each month.

These scopes of NDVI data were included in the analysis because of the logic in the spatial equilibrium model, which stated that commercial hub prices would be formed based on prices from markets over a wider geographic area than those of rural markets. It

[63] This is a somewhat different strategy than was implemented in Chapter 3. There, the price series with the highest adjusted-R^2 across the models associated with the 6 analyzed states was reported.
[64] Descriptions of the methods used to download these NDVI data and how the Northern Nigerian region was identified, are described in Chapter 2, Subsection 2.3.4, and Chapter 2, Appendix 2A.

is conceivable in the case of Kano State, which is home to Dawanau Market, a key grain market for trade across West Africa (Terpend 2006), that prices are influenced by growing conditions throughout the entire country. Borno and Katsina states, however, do not have such influential commercial hub markets, but are home to large urban areas. It is expected, therefore, that Kano State urban prices are influenced by growing conditions in Northern Nigeria to a larger degree than by state level growing conditions, while for Katsina and Borno states more local growing conditions may be more applicable. Inclusion of both NDVI scopes allows us to evaluate these conjectures.

Two types of production estimates were also used in the urban price models. These were estimates for national and state level production. The sources from which the national production estimates were obtained were those that had the highest relative correlation with the average growing season NDVI value for the full country and the production estimates[65]. The results in Chapter 2 showed somewhat high correlation between NBS and NPAFS data across crops. NPAFS data were included for all state production estimates and crops in order to maintain consistency. These production data were used to construct first difference variables, which are measures of year-to-year production changes, for inclusion in their associated models.

4.4.5 Rural model data

The rural models are also for Kano, Katsina, and Borno states. These models seek to explain the degree to which growing conditions affect rural prices in each state. The external prices for all of these models are the urban prices in each state. The rural prices were all obtained from NBS, and are statewide averages across multiple rural markets. All data are monthly observations for the period January 2007 to December 2010. The summary statistics for the Katsina State prices are in Chapter 4, Appendix 4A, and those for Kano and Borno states are in Chapter 3, Appendix 3B. The NDVI data for this set are

[65] For Northern Nigeria, the possible sources are the U.S. Department of Agricultural Production, Supply, and Distribution (USDA-PSD), FAOSTAT, Agricultural Market Information Service of the FAO (AMIS-FAO), the Nigerian National Bureau of Statistics (NBS), and the National Programme for Agriculture and Food Security (NPAFS) of the Nigerian Federal Ministry of Agriculture and Rural Development. The sources with the highest correlations for each crop were: USDA-PSD for maize, millet, and sorghum; and, FAOSTAT for rice, cassava, yams, and cowpeas. For each state, the possible data sources were NBS and NPAFS.

observations averaged across cropland area within the state border only, under the assumption that rural prices are primarily influenced by growing conditions at a more localized level. State production estimates were again annual observations obtained from NPAFS. These were used to construct first difference variables for state production estimates.

4.4.6 Local model data

The final set of models are associated with the three small, localized markets: Damasak, Borno; Daura, Katsina; and, Jibia, Katsina. The data from these markets were obtained from the World Food Programme VAM Food and Commodity Price Data Store[66]. They are available beginning in January 2007, but consistent estimates do not begin until January 2008. A table with summary statistics associated with these price series is included in Chapter 4, Appendix 4A.

Two NDVI scopes are included for the local set. These include measures across cropland within the state border, as well as a localized measure that includes only a few neighboring local government areas around each town. Production data are only at the state level, and are again those from NPAFS. The same first differenced state level production variables from the rural set were used in the local set models as well.

4.4.7 Data issues

The price data issues described in Chapter 3, section 3.4.5 apply for this analysis as well. Results for all crops are reported, however, despite the described transcription issue with the millet data in 2008, since exclusion of these data did not appear to impact results. Since the Kano State urban price data are missing for some crops for 2008, the rural models for Kano State have somewhat short three year series. Additionally, the WFP local price data are somewhat spotty for the full period January 2007-December 2010, but are nearly full for 2008-10 (with only a few months missing in early 2009).

[66] It is notable that within the World Food Programme VAM Food and Commodity Price Data Store there are only 5 total markets in Nigeria for which price data are available, and when they are available they are somewhat spotty. By contrast, there are prices for over 80 markets in Niger.

4.5 Empirical Results

Results from estimation of the levels and ECM models for the urban, rural, and local price sets are now discussed. Emphasis is placed on the ways in which the empirical analysis provides insights on key issues that pertain to the use of remote sensing data in price formation models. Table 4-1 below includes a list of the variables that are included in the levels and ECM models of each set. For the urban and local levels models, the lean season and NDVI anomaly interaction variables of different scopes were used in separate models associated with each scope (e.g., Northern Nigeria and state border for the urban set), and then a composite model was estimated that included the interaction variables associated with both scopes. For the ECM models, only one type of change in expected production variable was included in each model to supplement the standard external price first difference and lagged residuals from the levels model variables. These models were then estimated sequentially to allow for comparison across models, but did not include more than one change in expected production variable (i.e., there was no composite model).

Table 4-1: List of variables included in the levels and ECM models for the urban, rural, and local price model sets

Levels model variables	ECM model variables
Urban price set	
1) External price 2) Lean season and N. Nigeria NDVI downward anomaly interaction variable 3) Lean season and N. Nigeria NDVI upward anomaly interaction variable 4) Lean season and state level NDVI downward anomaly interaction variable 5) Lean season and state level NDVI upward anomaly interaction variable	1) Lagged residuals from levels model 2) External price first difference 3) N. Nigeria downward NDVI anomaly 4) N. Nigeria upward NDVI anomaly 5) State level downward NDVI anomaly 6) State level upward NDVI anomaly 7) Northern Nigeria NDVI first difference 8) State level NDVI first difference 9) National production first difference 10) State production first difference
Rural price set	
1) External price 2) Lean season and state level NDVI downward anomaly interaction variable 3) Lean season and state level NDVI upward anomaly interaction variable	1) Lagged residuals from levels model 2) External price first difference 3) State level downward NDVI anomaly 4) State level upward NDVI anomaly 5) State level NDVI first difference 6) State production first difference
Local price set	
1) External price 2) Lean season and state level NDVI downward anomaly interaction variable 3) Lean season and state level NDVI upward anomaly interaction variable 4) Lean season and local region NDVI downward anomaly interaction variable 5) Lean season and local region NDVI upward anomaly interaction variable	1) Lagged residuals from levels model 2) External price first difference 3) State level downward NDVI anomaly 4) State level upward NDVI anomaly 5) Local region downward NDVI anomaly 6) Local region upward NDVI anomaly 7) State level NDVI first difference 8) Local region NDVI first difference 9) State production first difference

Figures were created to combine presentation of the levels models and their associated ECM models. Figure 4-5 below is provided as an illustration. The levels models results are shown in the top half of the figure, and the associated ECM models are in the bottom half. The levels model with the highest adjusted-R^2 was chosen as the levels model for which the lagged residuals would be included in the second stage ECM models. The lines in the figure that highlight one of the levels models and link that model to all ECM models, signifying that the lagged residuals from that levels model were used in all ECM models in the bottom half of the figure. Thus, in figure 4-5, which shows the results for the urban maize price set for Kano State, the levels model with both pairs of interaction variables had the highest adjusted-R^2 value, and so the lagged residuals from that model were included in all ECM models. Some demonstrative example case results were chosen for illustration of how the results provide insights with regard to these four issues. Comprehensive results are provided in Appendix 4B of this chapter.

Levels models

	Base	with Northern Nigeria interactions	with Kano State interactions	with both interactions
Intercept	10.58*** (7.10)	10.93*** (7.38)	10.49*** (7.00)	10.05*** (6.63)
Maradi, Niger price	0.71*** (20.76)	0.69*** (19.75	0.70*** (19.66)	0.70*** (19.44)
LS x Northern Nigeria downward NDVI anomaly	…	0.08* (1.93)	…	0.09** (2.15)
LS x Northern Nigeria upward NDVI anomaly	…	0.06 (1.30)	…	-0.09 (-1.29)
LS x Kano State downward NDVI anomaly	…	…	0.01 (0.35)	0.00 (0.03)
LS x Kano State upward NDVI anomaly	…	…	0.09** (2.50)	0.15*** (2.75)
ADF	-6.77***	-4.40***	-7.27***	-7.72***
PP	-6.81***	-7.18***	-7.31***	-7.79***
Adj. R^2	0.80	0.81	0.81	0.82

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals levels model	-0.70*** (-7.11)	-0.69*** (-7.33)	-0.68*** (-6.57)	-0.69*** (-7.57)	-0.68*** (-7.40)	-0.67*** (-7.12)	-0.67*** (-7.18)
Maradi, Niger price first difference	0.61*** (5.05)	0.58*** (4.82)	0.64*** (5.20)	0.57*** (4.95)	0.57*** (4.85)	0.61*** (5.07)	0.61*** (5.12)
N. Nigeria downward NDVI anomaly	…	4.42** (2.02)	…	…	…	…	…
N. Nigeria upward NDVI anomaly	…	1.28 (0.52)	…	…	…	…	…
Kano State downward NDVI anomaly	…	…	0.38 (0.17)	…	…	…	…
Kano State upward NDVI anomaly	…	…	2.17 (1.40)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	19.20*** (2.87)	…	…	…
Kano State NDVI first difference	…	…	…	…	14.95** (2.52)	…	…
Nigerian national prod. first difference	…	...	…	…	…	-0.00 (-0.31)	…
Kano State prod. first difference	…	…	…	…	…	…	-0.02 (-1.36)
Adj. R^2	0.40	0.41	0.40	0.43	0.43	0.39	0.40
Adj. R^2 difference from Base	…	+0.01	0	+0.03	+0.03	-0.01	0

Figure 4-5: Kano State urban maize price levels and ECM model estimation results

Note: t-statistics are in parentheses. ***, **, and * denote 1%, 5%, and 10% statistical significance, respectively. Critical values for the ADF and PP statistics associated with stationarity tests of estimated residuals ($\hat{v}_t$) for n=100 are -2.60, -1.95, and -1.61; for n=50 are -2.62, -1.95, and -1.60, for 1%, 5%, and 10% levels, respectively. All critical values are provided in Fuller (1996). A statistically significant estimated ECM term ($\hat{\gamma}$) implies cointegration (Banerjee et al. 1986). LS is an abbreviation for "lean season".

4.5.1 NDVI as a proxy for expected production

Recall from the section on the relationship between agricultural production and NDVI that since NDVI can be reliably obtained monthly, they are likely to be some of the most informative data for changes in expected production in the months leading up to harvest. The NDVI, however, is only useful with regard to accurately estimating an actual volume of production from a base production estimate if that production estimate is accurate. While the NDVI and production estimates are expected to be correlated (in Chapter 2 it was found that this does not apply for Nigeria), more accurate production estimates would be expected to better reflect inter-crop year price changes than the NDVI alone. This follows from the NDVI representing changes in overall growing conditions, which is an incomplete measure relative to thorough agricultural farm production surveys that account for additional information such as crop mix and area allocations or input application adjustments. Thus, the crops for which there are more accurate production estimates are also those for which the prices are expected to be relatively better explained by production estimates than the NDVI. Those crops for which the production estimates are of the poorest quality (or unavailable) are those for which NDVI data are in the best position to serve as a proxy for expected production.

In foreshadowing a future issue, however, the degree to which changes in expected production explains price changes depends on the degree to which other factors such as the prices in other markets matter. In Chapter 3, it was observed that urban prices were primarily explained by prices in other urban markets or international prices. Thus, even if the NDVI data and production estimates were correlated for a given crop, the degree to which either variable matters for explanation of price changes depends on the structure of individual markets and their linkages with outside markets. The argument that accurate production estimates are relatively better suited for explanation of price changes than NDVI is, therefore, better suited for rural prices that are less influenced by external prices than urban prices. For these reasons, focus in this section is placed on rural and local prices only.

Results in Chapter 2 showed that state level production estimates were commonly mixed with regard to their correlation with NDVI, such that for most crops there was at least some (limited in most cases) evidence of correlation. There were a few distinct outliers, however, for the states examined here. The production estimates for sorghum and millet for Borno and Katsina states had, to a substantial degree, the lowest correlation estimates with the NDVI measures of all crops (as well as the least negative correlation with prices). The same was found for Kano State with rice. These cases are examined here, therefore, as representations of the cases with the least accurate production estimates. The NDVI anomaly variables are expected to have relatively more explanatory power than the state production first differences variables in these cases.

To discern whether the data are consistent with these propositions, the results for the Borno State rural sorghum price levels and ECM models results are presented below in figure 4-6. The results show that the only growing conditions related variable that has a coefficient that is statically significantly different from zero is the Borno State downward NDVI anomaly variable, and at the 5% level. This coefficient estimate is positive also, which is consistent with expectations in the case when demand and other supply conditions remain constant. The state production differences variable coefficient is not, however, statistically significantly different than zero. These results imply that for the case of rural Borno State sorghum prices, NDVI data are relatively more informative in explaining price changes than are state production estimates.

While this is just one example, in none of the other cases named above, for which the production estimates were found to be of poorest quality (Borno State millet, Katsina State millet and sorghum, and Kano rice), was the production difference variable in the associated ECM model found to be statistically significantly different than zero. In some of these cases, the NDVI anomaly variables were also statistically insignificant, but these findings appear generally applicable for the rural price set.

This pattern also extends to the local price set. The NDVI anomaly variables appear to explain millet and sorghum price changes relatively better than state level production estimates for each of Damasak, Borno, and Daura and Jibia, Katsina. In none of these cases was the coefficient associated with the production first difference variable statistically significantly different than zero. To illustrate further, the results for the Jibia, Katsina local millet price levels and ECM models are shown in figure 4-7 below. It is observed that the only variable with a coefficient that is statistically significantly different than zero is that associated with the local region NDVI downward anomaly variable, at a level very close to 5% significance. The inclusion of the local NDVI anomaly variables in this case greatly improves the average adjusted-R^2 relative to the base model, while the state level production estimates do not add any substantive information.

In summary, in the cases examined here, which were those for which the production estimates had previously been identified as of poorest quality, statistical evidence was found for the use of NDVI anomaly variables to explain price changes rather than production estimates. These findings support the use of NDVI data as a proxy for expected production, especially in the cases for which the production data are of poor quality or are unavailable. As Chapter 2 observed, the problem of poor quality production data is an important concern for Nigeria, both with regard to the methods used in data gathering and in the long delays in reporting that often persist for years. There may be other developing countries as well for which NDVI data are of better quality than production data.

Levels models

	Base	with interactions
Intercept	5.82 (1.11)	-1.69 (-0.29)
Borno State urban price	0.86*** (8.32)	1.02*** (8.80)
LS x Borno State downward NDVI anomaly	…	-0.11** (-2.12)
LS x Borno State upward NDVI anomaly	…	0.20 (1.66)
ADF	-6.04***	-0.98
PP	-6.00***	-6.02***
Adj. R^2	0.59	0.63

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.83*** (-5.20)	-0.87*** (-5.69)	-0.83*** (-5.17)	-0.80*** (-4.74)
Borno State urban price first difference	0.31 (1.63)	0.25 (1.38)	0.30 (1.56)	0.25 (1.09)
Borno State downward NDVI anomaly	…	6.79** (2.56)	…	…
Borno State upward NDVI anomaly	…	5.14 (1.52)	…	…
Borno State NDVI first difference	…	…	5.38 (0.53)	…
Borno State production first difference	…	…	…	0.04 (0.70)
Adj. R^2	0.35	0.44	0.34	0.34
Adj. R^2 difference from Base	…	+0.09	-0.01	-0.01

Figure 4-6: Borno State rural sorghum price levels and ECM model estimation results

Note: a description of the contents in the tables encompassed in this figure are included below figure 4-5.

Levels models

	Base	with state interactions	with local region interactions	with both interactions
Intercept	16.42 (1.47)	16.43 (1.24)	18.12 (1.24)	18.12 (1.24)
Katsina State urban price	0.61** (2.60)	0.61** (2.52)	0.58** (2.10)	0.58** (2.10)
LS x Katsina State downward NDVI anomaly	…	…	…	…
LS x Katsina State upward NDVI anomaly	…	0.00 (0.02)	…	0.01 (0.09)
LS x local region downward NDVI anomaly	…	…	0.03 (0.32)	0.03 (0.32)
LS x local region upward NDVI anomaly	…	…	0.01 (0.09)	…
ADF	-2.94***	-2.94***	-2.87***	-2.87***
PP	-2.96***	-2.96***	-2.91***	-2.91***
Adj. R^2	0.22	0.18	0.14	0.14

ECM models

	Base	with state NDVI anomalies	with local NDVI anomalies	with state NDVI first diffs.	with local NDVI first diffs.	with state production first diffs.
Lagged residuals base levels model	-0.51* (-2.03)	-0.51* (-1.76)	-0.60** (-2.59)	-0.57 (-1.75)	-0.57* (-1.88)	-0.44 (-1.59)
Katsina State urban price first difference	-0.20 (-0.36)	-0.38 (-0.65)	-0.05 (-0.10)	-0.22 (-0.37)	-0.24 (-0.41)	-0.29 (-0.49)
Katsina State downward NDVI anomaly	…	…	…	…	…	…
Katsina State upward NDVI anomaly	…	-3.29 (-1.04)	…	…	…	…
Local downward NDVI anomaly	…	…	-8.56* (-2.14)	…	…	…
Local upward NDVI anomaly	…	…	-3.00 (-0.93)	…	…	…
Katsina State NDVI first difference	…	…	…	7.35 (0.29)	…	…
Local region NDVI first difference	…	…	…	…	9.81 (0.37)	…
Katsina State production first difference	…	…	…	…	…	-0.50 (-0.63)
Adj. R^2	0.19	0.19	0.34	0.14	0.14	0.16
Adj. R^2 difference from base	…	0	+0.15	-0.05	-0.05	-0.03

Figure 4-7: Jibia, Katsina millet price levels and ECM model estimation results

Note: a description of the contents in the tables encompassed in this figure are included below figure 4-5.

4.5.2 How to incorporate NDVI

The previous section provided statistical evidence to support the use of NDVI data as a proxy for expected production, especially in the cases in which the production data are of poorest quality. The issue of how the NDVI data are to be incorporated is addressed in this section, through comparison of the relative explanatory power of the two types of examined NDVI variables: anomalies and first differences.

The prior discussion on interpretation of coefficients is pertinent once again. The natural cyclicality of NDVI data predispose it to capture the changes in prices that themselves are subject to the most cyclical, seasonal price patterns. The crops and areas for which this is most applicable are those that depend most heavily on rainfall as the primary source of precipitation. The crops and areas that are less dependent on rainfall are expected to be relatively more influenced by anomaly periods than first differences, simply because the intertemporal adjustments to growing conditions and other market conditions are less variable.

To investigate the accuracy of this conjecture, the focus is again placed on rural and local prices, since these prices are plausibly more heavily subject to variation in local factors such as production than are urban prices, as was found in Chapter 3. Figure 4-4 showed that Katsina State, Kano State, and the southern portion of Borno State are all part of the greater Niger River Basin. This implies that Borno State, and especially towns such as Damasak, Borno (in the Mobbar local government area) in the northwest region of Borno State, are likely to be relatively more rainfall dependent in general for agriculture than are Katsina and Kano states (which presumes likely existence of non-rainfall water availability in these states). Since the rural prices are averages across each state, however, they likely capture areas that depend on both rainfall and irrigation, which clouds the comparison across states to some degree.

Clearer comparisons could be applicable across local regions, however, since these are in areas with apparent contrasting geophysical characteristics. Based on the Nigerian river network shown in figure 4-4, Damasak, Borno is located in a region that does not appear to have an extensive river system, while Jibia, Katsina is surrounded by one. Thus, for the crops grown in each region (maize, sorghum, millet, and cowpeas), Damasak, Borno prices are conceivably relatively more influenced by continual changes in rainfall than are those in Jibia, Katsina. It follows that first differences in NDVI may be a more powerful explanatory factor behind price changes than anomalies in Damasak, Borno, while the opposite would be the case in Jibia, Katsina.

The rural price results are broadly consistent with the expectation that the nature of the data as state wide averages would cloud the relative efficacy of first differences versus anomaly measures. Figure 4-8 below shows the rural Borno State maize price results for the levels and ECM models. The results show that both the NDVI first differences and the downward growing season NDVI anomaly variables are statistically significantly different than zero at the 5% and 10% significance levels, respectively. In terms of the adjusted-R^2 values, the model that includes the NDVI first differences is higher than that associated with the growing season NDVI anomaly variables, but both increase the adjusted-R^2 from the base. The results for the rural price models for the other states are somewhat mixed, but broadly appear to be consistent with expectations of varied results. In the Kano State results, only anomaly variables, and no first differences variables, were statistically significant in that set. In the Katsina State rural price models, there was only one model for which either the growing season NDVI anomaly or first difference variable was statistically significantly different than zero (millet), and in that case it was the NDVI first difference that was statistically significantly different from zero (at the 5% level).

Levels models

	Base	with interactions
Intercept	25.63*** (4.94)	22.37*** (3.95)
Borno State urban price	0.51*** (5.38)	0.55*** (5.38)
LS x Borno State downward NDVI anomaly	…	0.03 (0.52)
LS x Borno State upward NDVI anomaly	…	0.28 (1.62)
ADF	-4.61***	-4.55***
PP	-4.51***	-4.45***
Adj. R^2	0.37	0.38

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.53*** (-3.62)	-0.63*** (-4.15)	-0.61*** (-4.21)	-0.61*** (-3.49)
Borno State urban price first difference	0.36** (2.50)	0.41*** (2.83)	0.35** (2.52)	0.36** (2.46)
Borno State downward NDVI anomaly	…	7.02* (1.79)	…	…
Borno State upward NDVI anomaly	…	4.47 (0.91)	…	…
Borno State NDVI first difference	…	…	30.50** (2.24)	…
Borno State production first difference	…	…	…	-0.02 (-0.09)
Adj. R^2	0.22	0.25	0.29	0.20
Adj. R^2 difference from Base	…	+0.03	+0.07	-0.02

Figure 4-8: Borno State rural maize price levels and ECM model estimation results

Note: a description of the contents in the tables encompassed in this figure are included below figure 4-5.

The local price model results are somewhat cleaner with regard to consistency. It was expected that NDVI first differences would be relatively more informative than anomaly measures in Damasak, Borno than Daura or Jibia, Katsina, which is found to be the case. Figure 4-9 below shows the estimation results for the Jibia, Katsina maize price levels and ECM models. The results show that the NDVI first differences do not add any information to explain Jibia, Katsina maize price changes. Both the statewide growing season NDVI downward anomaly and local region growing season NDVI anomaly variables are statistically significantly different from zero, however, and at the 5% statistical significance levels.

Levels models

	Base	with state interactions	with local region interactions	with both interactions
Intercept	38.02 (3.41)	44.09 (3.95)	39.51 (3.37)	46.68 (4.07)
Katsina State urban price	0.19 (1.00)	0.07 (0.33)	0.17 (0.80)	0.01 (0.03)
LS x Katsina State downward NDVI anomaly	…	0.20* (2.02)	…	0.23** (2.18)
LS x Katsina State upward NDVI anomaly	…	-0.02 (-0.20)	…	-0.01 (-0.08)
LS x local region downward NDVI anomaly	…	…	0.05 (0.50)	0.10 (0.98)
LS x local region upward NDVI anomaly	…	…	-0.04 (-0.32)	…
ADF	-4.67***	-3.65***	-4.90***	-3.25***
PP	-2.97***	-3.40***	-2.82***	-3.20***
Adj. R^2	0.00	0.07	-0.06	0.07

ECM models

	Base	with state NDVI anomalies	with local NDVI anomalies	with state NDVI first diffs.	with local NDVI first diffs.	with state production first diffs.
Lagged residuals base levels model	-0.28* (-1.82)	-0.39** (-2.63)	-0.32** (-2.18)	-0.38 (-1.41)	-0.38 (-1.61)	-0.28* (-1.78)
Katsina State urban price first difference	0.10 (0.45)	0.07 (0.29)	0.24 (0.99)	0.09 (0.40)	0.11 (0.40)	0.12 (0.48)
Katsina State downward NDVI anomaly	…	13.71** (2.56)	…	…	…	…
Katsina State upward NDVI anomaly	…	-2.13 (-0.56)	…	…	…	…
Local downward NDVI anomaly	…	…	-12.07** (-2.15)	…	…	…
Local upward NDVI anomaly	…	…	-1.44 (-0.32)	…	…	…
Katsina State NDVI first difference	…	…	…	14.35 (0.44)	…	…
Local region NDVI first difference	…	…	…	…	16.86 (0.55)	…
Katsina State production first difference	…	…	…	…	…	0.72 (0.28)
Adj. R^2	0.04	0.19	0.14	0.02	0.02	0.01
Adj. R^2 difference from base	…	+0.15	+0.10	-0.02	-0.02	-0.03

Figure 4-9: Jibia, Katsina maize price levels and ECM model estimation results

Note: a description of the contents in the tables encompassed in this figure are included below figure 4-5.

The positive sign associated with the coefficient for the downward growing season NDVI anomaly is consistent with there being no substantial changes in demand or non-harvest supply conditions. The negative sign associated with the analogous local downward growing season NDVI variable would then be associated with a change in demand or non-harvest supply conditions from the situation in which base expectations were formed. These contradictory signs foreshadow the issue in the next section with regard to the proper scope of NDVI data to use in an empirical analysis.

To summarize, the rural price results were broadly reflective of the conjecture that first differences measures of NDVI changes would be relatively more applicable in areas that rely primarily on rainfall precipitation for agricultural production than those areas that have potential for irrigation. There were, however, a few cases such as Borno State rural sorghum prices and Katsina State millet prices that diverged from this rule. This is likely due to the nature of the rural price data as being statewide averages, and thus, clouding the ability to clearly demarcate between these alternative measures. The results were more in line with expectations for local prices. For the Damasak, Borno price models, in no model was any of the growing season NDVI anomaly variables statistically significantly different from zero, while at least one of either the local or state level NDVI first differences variables was for all crops. There was only one ECM model (sorghum) in the Daura, Katsina set in which a coefficient associated with a NDVI variable was statistically significantly different than zero, and that was a growing season NDVI anomaly case. In the three ECM models with coefficients that were statistically significantly different from zero for Jibia, Katsina (maize, millet, and sorghum), these were all respectively for growing season NDVI anomaly variables. Thus, the results are broadly consistent with the conjecture that NDVI anomaly measures would be relatively more informative for local prices in Katsina State than in Borno State.

The results showed some cases in which both local and state level NDVI measures appeared to be explanatory for price changes. In the next section, this issue of the proper NDVI scope to use in analysis is addressed.

4.5.3 The relevant scope of NDVI data

The results examined thus far have shown that, in some cases, the degree to which NDVI or production data explain price changes varies with the geographic areas used to form measures of NDVI or production variables. For the urban price sets, two different NDVI scopes are included: Northern Nigeria and state borders. State borders and local regional areas are used for the local price set. Only the state border scope was used for the rural price set. The urban set included two scopes of production, national and state, while the rural and local set only included the state scope. It is proposed here that the proper scope to use in explanation of price changes for a given crop is a function of the market size as determined by interconnectedness of the market over an area frame (which has trade implications if the crop is consumed but not produced).

With regard to market size, if a city is a commercial hub, and, therefore, receives supplies from urban cities and local towns across a wide geographic range, then it is expected that growing conditions that are reflective of that wide range would be relatively more informative for prices than those that reflect a more localized area. For a commercial hub in Nigeria, such as Kano State, home of Dawanau Market, the Northern Nigeria NDVI scope would be expected to better reflect variation in urban Kano State prices than the statewide border scope. For all markets this is, however, conditional on their interconnectedness across markets, which was found in Chapter 3 to vary across crops.

Additionally, if a crop is not produced but consumed in a substantial quantity in a given state, then any consumption is met through trade. In such a case, such as for cassava and yams in the Northern Nigerian states, it would be expected that growing conditions over the wider area would be relatively more important than more localized growing conditions. If the crop is grown within only one smaller region that lies within the broader market size area, then both local and regional effects may be important.

To examine the conjecture that relatively larger scopes would be more important for commercial hub than non-commercial hub markets, and for crops that are not produced but consumed locally, results from the urban and local sets are consulted. With regard to the urban price set, figure 4-10 below shows the results for the urban Kano State cassava price levels and ECM models. The results for the ECM models show that the only model for which there is an associated growing conditions related variable that has a coefficient that is statistically significantly different from zero is that which includes a growing season NDVI anomaly variable. In that model, only the growing season Northern Nigeria downward NDVI anomaly variable coefficient was statistically significant, and at the 1% significance level. This estimate implies that periods in which there is a downward growing season NDVI anomaly for Northern Nigeria are associated with higher urban cassava prices in Kano State. This intuitively makes sense since, holding demand and non-harvest supply effects constant, declines in aggregate supply of other staple foods in downward anomaly periods would cause increased demand (e.g., substitution effects in consumption) for crops grown outside the region (like cassava, which is primarily grown in Southern Nigeria). For the other crops in the Kano State set, yams was the only exceptional case such that only the coefficient associated with a NDVI variable with a state level scope was statistically significantly different from zero, while the analogous variable with the Northern Nigeria scope was not.

These patterns of results for Kano State broadly apply for Borno State as well, which is not surprising given the strong linkages between urban markets in Borno and Kano states found in Chapter 3. The exception crop for Borno State was cowpeas. In this case, the state production estimate was more informative than the larger scope production or any NDVI measures. The Northern Nigeria scope was at least as informative as the state level scope for explanation of urban price changes in Katsina State for most crops, although it was more commonly the case that none of the expected production variables was statistically significantly different than zero than was the case for the other states. For the maize and yams models, none of the growing conditions related variable coefficients were statistically significantly different from zero. This is likely due to Katsina State urban prices having strong interconnectedness with external markets, as seen in the estimated price transmission parameters in the levels models that all approach 1. An estimated price transmission parameter equal to 1 implies full price transmission, leaving little information to be explained by local conditions such as weather.

Levels models

	Base	with Northern Nigeria interactions	with Kano State interactions	with both interactions
Intercept	12.72*** (4.65)	12.81*** (5.12)	11.29*** (4.26)	10.76*** (4.43)
Malanville, Benin price	1.10*** (19.96)	1.08*** (20.98)	1.17*** (21.10)	1.15*** (22.48)
LS x Northern Nigeria downward NDVI anomaly	…	0.27*** (4.25)	…	0.27*** (4.65)
LS x Northern Nigeria upward NDVI anomaly	…	-0.13* (-1.67)	…	-0.17* (-1.66)
LS x Kano State downward NDVI anomaly	…	…	-0.20*** (-3.43)	-0.21*** (-3.96)
LS x Kano State upward NDVI anomaly	…	…	-0.11* (-1.81)	0.01 (0.15)
ADF	-5.59***	-6.90***	-5.90***	-7.31***
PP	-5.50***	-6.89***	-5.89***	-7.37***
Adj. R^2	0.80	0.83	0.82	0.85

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.51*** (-5.56)	-0.53*** (-6.38)	-0.51*** (-5.59)	-0.51*** (-5.60)	-0.51*** (-5.54)	-0.50*** (-5.40)	-0.50*** (-5.38)
Malanville, Benin price first difference	0.41*** (2.95)	0.38*** (2.92)	0.40*** (2.83)	0.40*** (2.84)	0.40*** (2.87)	0.40*** (2.81)	0.41*** (2.94)
Northern Nigeria downward NDVI anomaly	…	13.29*** (4.38)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	2.31 (0.68)	…	…	…	…	…
Kano State downward NDVI anomaly	…	…	1.89 (0.72)	…	…	…	…
Kano State upward NDVI anomaly	…	…	-2.59 (-1.05)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	12.82 (1.16)	…	…	…
Kano State NDVI first difference	…	…	…	…	7.18 (0.75)	…	…
Nigerian national prod. first difference	…	…	…	…	…	0.00 (0.61)	…
Kano State prod. first difference	…	…	…	…	…	…	-0.02 (-0.21)
Adj. R^2	0.24	0.36	0.24	0.24	0.24	0.24	0.23
Adj. R^2 difference from Base	…	+0.12	0	0	0	0	-0.01

Figure 4-10: Kano State urban cassava price levels and ECM model estimation results

Note: a description of the contents in the tables encompassed in this figure are included below figure 4-5.

In the local Damasak, Borno price set, there were either cases in which both the state and local NDVI scope variable coefficients were statistically significantly different from zero, or only the local scope anomaly variable coefficients were statistically significantly different from zero. There were no cases in which only the coefficient associated with the state level scope was statistically significantly different from zero. For illustration, the results for Damasak, Borno maize price levels and ECM models are shown below in figure 4-11. The results show that both the state and local level NDVI first difference variable coefficients are highly statistically significantly different from zero (each at the 1% level), and the addition of these variables improves the adjusted-R^2 by 0.30 or more. Both the levels and ECM model estimated price transmission parameters imply that the Damasak, Borno maize prices do not often achieve equilibrium with the average Borno State urban prices. In cases such as this, in which the interconnectedness across markets is low, then a relatively more localized NDVI measure may be appropriate. Some statistical evidence to support this claim is found with the coefficient associated with the local growing season NDVI downward anomaly variable that is statistically significantly different from zero at the 5% significance level. The coefficient sign is negative, which is unexpected from the perspective of constant demand and other supply factors, but nonetheless suggests that local NDVI measures may be relatively more applicable than broader measures in particularly isolated markets.

While the results for Jibia, Katsina are similar to those for Damasak, Borno, the Daura, Katsina results present a contrasting case. The Daura, Katsina levels models have broadly higher estimated price transmission coefficients than those of Jibia and Damasak. This implies that Daura, Katsina markets are broadly more interconnected with urban markets than are Jibia and Damasak markets. This greater relative interconnectedness of Daura with external markets as estimated by the price transmission parameters results in smaller effects of local NDVI variables than was the case for Jibia and Damasak. Indeed, none of the local region NDVI nor production variable coefficients for any of the Daura, Katsina models was statistically significantly different from zero. The analogous state scope variable coefficient was statistically significantly different from zero for sorghum (and nearly so for maize and millet), however, which provides further evidence to support the conjecture that larger NDVI scopes are better suited for markets that are relatively more interconnected.

Levels models

	Base	with state interactions	with local region interactions	with both interactions
Intercept	44.07*** (5.90)	44.23*** (5.92)	44.32*** (5.85)	44.32*** (5.85)
Borno State urban price	0.13 (1.05)	0.12 (0.94)	0.11 (0.37)	0.11 (0.91)
LS x Borno State downward NDVI anomaly	…	…	…	0.03 (0.43)
LS x Borno State upward NDVI anomaly	…	0.05 (0.99)	…	…
LS x local region downward NDVI anomaly	…	…	0.03 (0.43)	…
LS x local region upward NDVI anomaly	…	…	0.08 (1.01)	0.04 (0.43)
ADF	-3.96***	-3.82***	-3.89***	-3.89***
PP	-3.30***	-3.36***	-3.34***	-3.34***
Adj. R^2	0.00	0.00	-0.03	-0.03

ECM models

	Base	with state NDVI anomalies	with local NDVI anomalies	with state NDVI first diffs.	with local NDVI first diffs.	with state production first diffs.
Lagged residuals base levels model	-0.46*** (-3.01)	-0.49*** (-3.03)	-0.50*** (-3.52)	-0.83*** (-5.62)	-0.60*** (-4.78)	-0.46*** (-2.96)
Borno State urban price first difference	0.08 (0.65)	0.09 (0.77)	0.11 (1.00)	0.05 (0.56)	0.01 (0.16)	0.07 (0.62)
Borno State downward NDVI anomaly	…	2.84 (0.93)	…	…	…	…
Borno State upward NDVI anomaly	…	0.13 (0.02)	…	…	…	…
Local downward NDVI anomaly	…	…	-6.61** (-2.49)	…	…	…
Local upward NDVI anomaly	…	…	3.98 (1.47)	…	…	…
Borno State NDVI first difference	…	…	…	49.97*** (4.27)	…	…
Local region NDVI first difference	…	…	…	…	36.05*** (4.22)	…
Borno State production first difference	…	…	…	…	…	-0.02 (-0.16)
Adj. R^2	0.20	0.16	0.35	0.51	0.50	0.17
Adj. R^2 difference from base	…	-0.04	+0.15	+0.31	+0.30	-0.03

Figure 4-11: Damasak, Borno maize price levels and ECM model estimation results

Note: a description of the contents in the tables encompassed in this figure are included below figure 4-5.

4.5.4 Long-run price effects of weather changes

In the previous section, statistical evidence was found to support the argument that prices for markets that are more interconnected with external markets, if they are influenced by weather at all, are better explained by growing conditions over a relatively wide geographical area than a narrow one. In this section, the focus remains on those markets that are interconnected with other markets, but for which those interconnections may occasionally be become tighter during the lean seasons when an extreme harvest is expected.

The theory section above proposed that some conditions may exist in which the lean season market structure may change. In a typical lean season with normal growing conditions, the interconnectedness with external markets are average (or perhaps a bit above average as local sellers leave the markets, perhaps due to low marketable supplies, as proposed by Sarkar (1993)). In lean season periods, however, in which there is either an upward or downward NDVI anomaly, there is plausibly more outflows or inflows of food crops than in normal condition periods if the parity bounds are binding and arbitrage is efficient. This implies that if there is an expected production anomaly during the growing season, then as farmers and traders implement transactions on those expectations, prices are more likely to reach the parity bounds and so price correspondence between the rural and external markets would be higher than before expectations were formed. Since the expectations of harvest may be a couple of months in advance of harvest, the higher price correspondence may persist for some months. The proposition is, then, that expectations based on changes in growing conditions may not only have short-run, but also long-run effects.

To examine this proposition empirically, attention is placed on the levels model parameters associated with the "lean season expected harvest anomaly" interaction variables. For initial illustration, the results for the Katsina State urban sorghum price levels and ECM models are shown in figure 4-12 below. The results show that the coefficients associated with the interaction terms that identify the periods in which it is a lean season and there is a downward growing season NDVI anomaly in Northern Nigeria and/or a downward growing season NDVI anomaly in Katsina State are statistically significantly different from zero at the 1% and 5% significance levels, respectively. This implies that in both of these types of periods, the interconnectedness between sorghum markets in Katsina State and Niamey, Niger is greater than in normal periods. Presumably this would be associated with greater inflows and/or outflows of sorghum between Niamey and Katsina State, but presently unavailable quantity data would be needed to verify this.

These results support the conjecture that the intersection of market structure and weather effects can cause long-run effects on the seasonal variation of prices, are somewhat general across the analyzed states and crops. Of the 24 state and crop combinations in the urban price analysis, there were only 7 for which there was no levels model interaction variable that had an estimated coefficient that was statistically significantly different than zero. Hence, growing conditions related changes in long-run expectations are frequently found.

While the interconnectedness between urban and rural prices was observed to be broadly lower than across urban markets, the interconnectedness between urban and rural prices, when it exists, may also plausibly be different in periods where the market conditions are as described above. The example case results of Kano state rural cowpeas price levels and ECM models are presented in figure 4-13 below. Those results show that the coefficient associated with the interaction term that indicates the lean season periods in years for which there is a downward growing season NDVI anomaly in Kano State is statistically significantly different from zero at the 1% significance level. This estimate implies that urban and rural cowpea markets are relatively more interconnected during lean seasons with downward growing season anomalies than in normal times. It also is consistent with a binding import parity bound, but with slow and imperfect arbitrage.

Levels models

	Base	with Northern Nigeria interactions	with Katsina State interactions	with both interactions
Intercept	-3.12 (-1.34)	-3.74* (-1.71)	-2.52 (-1.10)	-3.08 (-1.43)
Niamey, Niger price	0.89*** (19.02)	0.88*** (19.98)	0.86*** (18.34)	0.86*** (19.64)
LS x Northern Nigeria downward NDVI anomaly	…	0.23*** (4.51)	…	0.26*** (3.94)
LS x Northern Nigeria upward NDVI anomaly	…	-0.04 (-0.76)	…	0.00 (0.01)
LS x Katsina State downward NDVI anomaly	…	…	0.16** (2.24)	0.17** (2.47)
LS x Katsina State upward NDVI anomaly	…	…	0.05 (1.33)	-0.03 (-0.53)
ADF	-4.04***	-4.13***	-4.12***	-4.42***
PP	-4.58***	-4.83***	-4.79***	-5.14***
Adj. R^2	0.75	0.79	0.76	0.80

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.27*** (-3.62)	-0.28*** (-3.88)	-0.27*** (-3.58)	-0.25*** (-3.41)	-0.25*** (-3.42)	-0.27*** (-3.59)	-0.26*** (-3.58)
Niamey, Niger price first diff.	0.48*** (3.60)	0.46*** (3.47)	0.49*** (3.59)	0.39*** (2.88)	0.37*** (2.71)	0.48*** (3.55)	0.48*** (3.58)
Northern Nigeria downward NDVI anomaly	…	4.72* (1.96)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	0.93 (0.35)	…	…	…	…	…
Katsina State downward NDVI anomaly	…	…	0.34 (0.14)	…	…	…	…
Katsina State upward NDVI anomaly	…	…	0.51 (0.37)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	17.55** (2.44)	…	…	…
Katsina State NDVI first difference	…	…	…	…	18.46*** (2.67)	…	…
Nigerian national prod. first difference	…	…	…	…	…	-0.00 (-0.11)	…
Katsina State prod. first difference	…	…	…	…	…	…	0.01 (0.13)
Adj. R^2	0.15	0.16	0.13	0.18	0.19	0.14	0.14
Adj. R^2 diff. from Base	…	+0.01	-0.02	+0.03	+0.04	-0.01	-0.01

Figure 4-12: Katsina State urban sorghum price levels and ECM model estimation results

Note: a description of the contents in the tables encompassed in this figure are included below figure 4-5.

Levels models

	Base	with interactions
Intercept	45.63*** (4.85)	47.82*** (5.89)
Kano State urban price	0.38*** (5.70)	0.36*** (5.86)
LS x Kano State downward NDVI anomaly	…	0.18*** (3.84)
LS x Kano State upward NDVI anomaly	…	-0.06 (-1.27)
ADF	-4.33***	-5.60***
PP	-4.42***	-5.59***
Adj. R^2	0.40	0.56

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.58*** (-3.43)	-0.57*** (-3.49)	-0.65*** (-3.83)	-0.60*** (-3.47)
Kano State urban price first difference	0.13 (1.08)	0.18 (1.48)	0.15 (1.22)	0.14 (1.12)
Kano State downward NDVI anomaly	…	12.09* (1.91)	…	…
Kano State upward NDVI anomaly	…	16.37 (1.41)	…	…
Kano State NDVI first difference	…	…	51.65* (1.73)	…
Kano State production first difference	…	…	…	-2.78 (-0.63)
Adj. R^2	0.17	0.24	0.21	0.16
Adj. R^2 difference from Base	…	+0.07	+0.04	-0.01

Figure 4-13: Kano State rural cowpeas price levels and ECM model estimation results

Note: a description of the contents in the tables encompassed in this figure are included below figure 4-5.

This result for the Kano State rural cowpeas markets is not, however, as generally applicable for rural prices as was the case for urban prices. Of the 24 possible state and crop combinations, there were 10 cases in which there was a coefficient associated with a lean season and anomaly period interaction variable that was statistically significantly different from zero. These cases were scattered across crops and states such that a common pattern is not easily discernible. The relatively low number of cases in which there were observed long-run effects on rural prices is plausibly because the rural price series are of short length relative to the urban price series. The relatively short rural price series means that an anomaly may not have been realized in the sample time frame.

4.5.5 Results summary

The results discussed above provided some insights into the usefulness of NDVI data as a proxy for agricultural production estimates, the appropriate ways to incorporate and measure NDVI data over space for markets with differing socioeconomic and geophysical characteristics, and whether NDVI data can help identify long-run price effects during periods in which the market structure plausibly changes. In doing so, there was much emphasis placed on the importance of geophysical and market structural characteristics of markets in each state, in order to show that different methods and variable measures may apply for different circumstances.

To highlight the degree to which NDVI and production data are helpful for explanation of price variation and price changes in each state in general, the levels and ECM models for each crop that had the highest adjusted-R^2 values were identified. Next, the adjusted-R^2 values of these models were compared to that of the base model with no NDVI or production information to obtain a measure of the increase in adjusted-R^2 value from the base (if no increase then this measure is zero). These increases in adjusted-R^2 values were then averaged across crops to obtain an average increase in adjusted-R^2 value for both the levels and ECM models obtained from inclusion of the NDVI and production data for each of the examined urban, rural, and local markets[67]. These averages are included in table 4-2 below.

[67] For example, for the levels models for the Borno State urban price set, the increase (rounded) in adjusted-R^2 value for each crop were: maize, 0.01; millet, 0; sorghum, 0.03; local rice, 0.01; imported rice, 0.01; cassava, 0.04; yams, 0.11; and, cowpeas, 0. The rounded average of these values is then 0.03.

Table 4-2: Average increase in adjusted-R^2 across crops for the levels and ECM models in each state set that had the highest individual adjusted-R^2 value across models in that set

	Levels models	ECM models
	Borno State	
Urban	0.03	0.04
Rural	0.02	0.05
	Kano State	
Urban	0.02	0.06
Rural	0.03	0.02
	Katsina State	
Urban	0.02	0.02
Rural	0.02	0.06
	Local	
Damasak, Borno	0	0.19
Daura, Katsina	0.05	0.05
Jibia, Katsina	0.04	0.11

The results in table 4-2 broadly show that the NDVI and production information explains both price variation, reflected in the averages for levels models, and price changes, reflected in the averages for the ECM models, better for local prices than urban and rural prices. NDVI and production information was most informative for explanation of local price changes in Damasak, Borno and Jibia, Katsina, which respectively had the largest average increases in adjusted-R^2 from the base models. This implies that, consistent with the results in Chapter 3 of broadly lesser connectivity between rural and urban markets than among urban markets, prices in the most isolated local markets are explained to a greater relative degree by growing conditions changes than are urban or rural prices that are aggregated across space.

While these broad trends of greater relative explanatory power for local relative to urban and rural prices are consistent with expectations, there is much variation in the degree to which NDVI and production information are informative for different crops. Table 4-3 below provides a broad summary that emphasizes the relative usefulness of production or NDVI data for explanation of long-run or short-run prices at the different scales of analysis (urban, rural, and local), and across crops. The measures included in table 4-3 are the average increases in the adjusted-R^2 from the base value (if there was not an increase then the value included in the average is zero) across the models with the highest adjusted-R^2 values for each category of models[68].

Table 4-3: Average increase in adjusted-R^2 across states for the levels and ECM models in each respective state set that had the highest individual adjusted-R^2 value across models in that set

	Levels models	ECM models
maize		
Urban	0.01	0.01
Rural	0.01	0.05
Local	0.04	0.19
millet		
Urban	0	0.03
Rural	0.02	0.06
Local	0	0.13
sorghum		
Urban	0.03	0.03
Rural	0.04	0.04
Local	0.11	0.13
local rice		
Urban	0.02	0.06
Rural	0.01	0.07
Local	0	0.09
imported rice		
Urban	0.01	0.02
Rural	0.01	0.03
Local	0	0.06
cassava		
Urban	0.04	0.06
Rural	0.02	0.03
Local	…	…
yams		
Urban	0.04	0.04
Rural	0.02	0.02
Local	…	…
cowpeas		
Urban	0.01	0.06
Rural	0.05	0.06
Local	…	…

[68] For example, for the urban price set, the increase (rounded) in the adjusted-R^2 value from the base for the levels models with the highest adjusted-R^2 value for the Kano, Borno, and Katsina State sets were 0.02, 0.01, and 0, respectively. Thus, the rounded average increase in adjusted-R^2 for the best urban maize levels models across states was 0.01.

It is observed in table 4-3 that NDVI and production information is most informative for explaining price variation and price changes for the crops predominantly produced in Northern Nigeria: maize, millet, sorghum, local rice, and cowpeas[69]. For these crops, the NDVI and production information improve most strongly the performance of the local ECM models, with increases in average adjusted-R^2 by nearly 0.20 for maize and above 0.10 for millet and sorghum. The increases in adjusted-R^2 that resulted from inclusion of NDVI or production data for explanation of cassava and yams rural price changes were lower than for all other crops. The growing conditions variables were, however, better in explaining urban price variation (as reflected in the adjusted-R^2 for the urban levels models) for cassava and yams than for other crops (rice, as expected, is an intermediate case). These results are plausibly reflective of substitution effects for consumption of these crops that are mostly grown in Southern Nigeria and subject to less rainfall variability. The implication of the results is that NDVI and production information are most useful for explanation of local price variation and changes in prices for crops grown in a region, but may also be somewhat useful for explanation of price variation for crops that are consumed but not extensively produced in the region (presumably due to substitution effects in consumption).

4.6 Concluding Remarks

There were multiple discoveries in this analysis that provide useful guidance with regard to the use of NDVI and production data in agricultural price formation models. The broad conclusions that were achieved from the empirical results in this study are in line with the expectations, based on the results of relatively low interconnectedness between rural and urban markets found in chapter 2, that NDVI data and production information would be relatively more informative for explanation of local prices than urban or rural prices that are averaged over space. There was some variation across markets with different geophysical and socioeconomic characteristics. The results imply that NDVI and production data are relatively useful in areas that primarily rely on rainfall

[69] Cassava and yams are grown in some states in Northern Nigeria, but in lesser quantities than is the case in Central and Southern Nigeria. The amount of cassava and yams produced in Northern Nigeria is also small compared to other crops.

in agricultural production (such as Damasak, Borno). The degree to which these data are informative for price variation and price changes over time was also found to vary across crops. Those crops that are widely produced within the region of observation (maize, millet, sorghum, local rice, and cowpeas for this case of Northern Nigeria) were those for which the NDVI and production data were relatively more informative for explanation of price changes. These data were, however, also found to explain price variation for crops not widely grown but consumed in the region (cassava and yams), plausibly reflecting substitution in consumption.

The improvements in price formation model performance, measured as the amount by which model adjusted-R^2 increased from a base model that did not include growing conditions data, however, were broadly relatively small. The main exception case was that for Damasak, Borno, which is a town that is not in a region with extensive river networks. This characteristic means that farmers in or near Damasak, Borno are largely reliant on rainfall for agricultural production, and variability in growing conditions is greater than elsewhere. Long and short-run estimated price transmission parameters from urban Borno State markets to Damasak were estimated to be broadly low for all crops (the long-run estimated price transmission parameter was somewhat high for local rice only). These results imply that, even though growing conditions are quite informative for Damasak prices, other non-weather local factors, such as transportation infrastructure, crop storage facilities, information networks, and other local market structure factors are likely to also be key explanatory factors of changes of these prices. The low adjusted-R^2 increases across all models from inclusion of production or NDVI implies that local conditions variables are likely to be more informative for explanation of price changes for markets in regions to the north of Nigeria in the Sahel, and in Southern and Eastern Africa, which are relatively more reliant on variable/uncertain rainfall for agricultural production than many regions in Nigeria. This especially applies for markets that are isolated and subject to high transactions costs.

In addition to these broad discoveries, this paper contributes to the price formation literature that uses NDVI to explain prices in a number of ways. The thorough theoretical discussion justifies the use of NDVI and production data for reasons based on economic theory. The theoretical discussion provided key reasoning for why weather effects matter for prices in general, and provided characteristics of markets that determined the relative degree to which the growing conditions affect prices.

The empirical analysis sheds light on four main issues. The first issue addressed was whether NDVI data are a suitable proxy for expected production. The results showed that actual production data were found to be commonly useful for explanation of price variation and price changes when those data are plausibly accurate and available, but that NDVI data were informative for the crops that were determined in Chapter 2 to have the lowest quality production data or where data are unavailable (for the states examined here these were millet and sorghum).

The next issue involved the manner in which NDVI data are to be incorporated, as anomalies or first differences. The results of this study, especially for the local price models, were consistent with the conjecture that NDVI first differences would likely be relatively more informative for explanation of price changes for the crops grown in regions that are primarily reliant on rainfall for precipitation. This conjecture followed from theory based in part on the anticipatory price model of Working (1958) in which expectations for production are continually updated throughout a growing season leading up to harvest. Previous studies such as Brown and Kshirsagar (2015) and Baffes, Kshirsagar, and Mitchell (2015) have utilized NDVI anomalies only, so the empirical investigation in this study is a subtle methodological expansion that is justified with economic theoretical foundations and our empirical discoveries.

The third issue of focus pertained to the issue of the proper scope of NDVI or production data to include in the analysis. It was proposed herein that market structure characteristics, such as market size and interconnectedness, would be key for strategic choice of observation areas. This was based in part on the theoretical foundations of the spatial equilibrium model of Ravallion (1986). The findings in the empirical analysis supported the conjecture that larger NDVI and production data scopes (e.g., Northern Nigeria rather than a state border) were relatively more applicable for markets with many linkages (which can be determined based on the estimated price transmission parameters in the models in this analysis, and more comprehensively, in Chapter 3). Expected production information, however, is less informative of price variation for cases of highly interconnected markets for which the prices are primarily determined by prices in other markets.

The final issue that was investigated pertained whether measures of expected production are helpful for explanation of long-run relationships among prices in spatially separated markets, in addition to explanation of short-run price variation. It was conjectured based on the theories of spatial equilibrium and parity bounds that expectations for extreme harvests that are formed during the growing season could plausibly cause farmers and traders to implement market transactions, which can cause shifts in parity bounds regimes, and hence, change longer run price relationships. Since expectations may be formed months in advance of harvest, if the change in price causes rural prices to rise or fall to achieve parity with the external price, and arbitrage is reasonably efficient, then they may co-move for some months. Hence, the potential exists for expectations to change price relationships under situations in which extreme harvests are expected. The empirical analysis was supportive of this conjecture to apply generally across crops and states for the urban price set, and somewhat applicable for the rural price set. This is plausibly because urban markets are more interconnected with external markets than rural markets and have parity bounds that are narrower, so even relatively small changes in prices due to extreme expected harvest can cause prices across markets to co-move to a greater degree than in periods of normal expected harvests. Since rural markets have wider parity bounds, the changes in prices that result from expectations may not be large enough or the markets may not be efficient enough to cause arbitrage to occur quickly, so the relationship with the external market only change substantially in cases of the most extreme harvests or when other factors adjust the external price or transactions costs to encourage arbitrage. This issue appears to be worthy of further investigation in other contexts, and with rural price series that are longer and complemented with similarly long price series from plausibly linked external markets.

CHAPTER 5. CONCLUSION

5.1 Results Summary

The goal of this dissertation was to provide a comprehensive assessment of the current state of conditions and operations in Nigerian food markets. The results of the three studies are instructive for policymakers and stakeholders who work in these markets. They provide clear insights with regard to worthwhile efforts in data gathering, food policy interventions, and future studies that could improve upon current conditions.

The study in Chapter 2 provides a concerning picture of the current state of the agricultural statistics system in Nigeria. Adjustments in the production estimates over time appear to reflect changes in (weak) data gathering methodology rather than changes in growing conditions. The study had a unique design that employed multiple forms of "on the ground" information -- prices and remote sensing (NDVI) data -- to validate whether available production estimates accurately reflect local conditions. This verification strategy was needed because of the absence of an agricultural census, which has not been undertaken in Nigeria since before the 1980's (Onyeri 2011). With no agricultural census, there is no outside source of verification for existing statistics and no comprehensive survey from which to obtain representative samples. There is, thus, no plausible way to aggregate data in a manner that is reflective of local conditions. The methodological approach of using alternative types of data that capture growing conditions could be used in other countries for which there is presently not an available objective verification source such as an agricultural census to undertake similar assessments.

The results from the study in Chapter 2 show that Nigerian agricultural production estimates are broadly poorly correlated with both prices and the remote sensed data (NDVI), but prices and NDVI are highly correlated with each other, and in a manner consistent with expectations. These results imply that Nigerian agricultural production estimates, in general, do not reflect local conditions, and, are, thus, of poor quality. Researchers who use these data in empirical analyses are, therefore, advised to do so with caution.

The comprehensive set of results in the price transmission analysis in Chapter 3 provides an extensive description of how well Nigerian food markets are connected within the country and with international markets. Nigerian food prices poorly co-move with prices on global markets. The exception crop among those analyzed here was rice. Coarse grain prices in Nigeria, such as maize, for which there are records of some imports since 2000 in the UN Comtrade data, are poorly connected to those on global markets. This does not mean that coarse grains, however, are non-traded "home goods" for Nigeria. Estimated high co-movement between coarse grain prices in Nigeria and those of its neighbor countries implies that these markets are closely connected and substantial trade occurs. The cross-border connections are more extensive in terms of the number of neighboring countries than would be assumed from only looking at UN Comtrade trade flow data or reports on regional trade flows such as CILSS (2015). These results imply that rice trade flows widely across both land borders and through the ports in Southern Nigeria, but coarse grains are primarily traded internationally across land (with neighboring countries). For rice and coarse grains imported from global markets, large margins were estimated, but with some regional differences for coarse grains. Large margins were estimated to apply for all regions for rice, but only for Southern Nigeria for coarse grains. The existence of these estimated margins implies that there are either transactions costs or quality premiums that vary systematically with the world price and/or mark-ups by traders with market power.

With regard to internal markets, Nigerian urban prices for most crops co-move strongly, but with long lags. For most crops and regions the urban prices are more closely linked than are urban and rural prices. Maize was exceptional in this regard in that the average urban-to-rural price co-movement was higher than the average between urban markets. Despite these averages, urban and rural prices for Borno State in Northeast Nigeria were estimated to be quite disconnected. These results imply that prices in some rural markets, especially in Northern Nigeria, are relatively more influenced by local conditions (e.g., weather) than trade with other markets.

The final study in Chapter 4 supplemented the price models from Chapter 3 with remote sensing NDVI data to estimate the degree to which growing conditions can explain price variation in Northern Nigerian markets. The study expands on the emerging literature comprised of the studies by Brown and Kshirsagar (2015) and Baffes, Kshirsagar, and Mitchell (2015) through provision of a thorough explanation of the theoretical relationship between growing conditions and prices, and an empirical investigation into four issues that have arisen in the literature. Namely, the study provides evidence to support: use of NDVI data in price formation models, especially when production estimates are unavailable or of poor quality; inclusion of NDVI first difference variables for explanation of price variability for price series with particularly pronounced seasonality, but NDVI anomalies for less seasonal price series; determination of the area scope used to average NDVI values across space through assessments of market size, as determined by market interconnectedness and concentration of production; and, examination of long-run effects of expectations formed on upcoming harvests that are in the lower tails of historical harvest distribution on price relationships, since transactions implemented based on those expectations cause movements of prices that induce arbitrage by farmers and/or traders.

Some main takeaways from the study in Chapter 4 are that, even though many rural markets appear disconnected from urban markets based on the findings in Chapter 3, the degree to which growing conditions changes, as captured by NDVI, explain price variation after the external prices are accounted for is low. Growing conditions were estimated to have the most explanatory power in the local price models, and for examination of short-run price changes. Even in these cases, however, the combined explanatory power of external price and growing conditions is low, which implies that other local factors (e.g., transportation costs for trade facilitation) are relatively more important for explanation of price movements in these markets. The results of both poor price transmission and relatively low growing conditions effects are plausibly explained by the seasonal and intermittent nature of marketing between urban and rural areas, and the geophysical characteristics of Nigeria such that many areas are less rainfall dependent than other parts of SSA.

5.2 Food Security Implications

The broad characterization of the food security problem that arises out of this dissertation is that it is primarily an issue of urban and rural poverty in the context of intermittent price instability that arises due to unexpected changes in growing conditions, external prices, and/or transactions costs. Results in Chapters 3 and 4 of this dissertation show that local markets are broadly disconnected, which implies that there is a massive need for public and private investment in economic factors that can better facilitate trade (e.g., infrastructure, information systems, and credit markets) to rural areas where many farmers reside and do business. These investments would improve market efficiency. If other investments in agricultural research, which are strategically linked with agribusiness development initiatives in markets that have the highest future growth potential to meet domestic or export demand (ideally identified with accurate empirical analyses), are also implemented, then there would likely be progress in achievement of broader agricultural sector growth and poverty reduction.

A main finding in Chapter 2 is that better quality agricultural statistics data are needed at the local, state, and national levels in Nigeria. Improvement of the quality and timeliness of data reports would improve the overall efficiency of the agricultural economy and increase overall economic welfare (Hayami and Peterson 1972). Improved data would also allow policymakers to establish accurate benchmarks for current conditions from which the impact of a policy can be measured. Without an accurate benchmark, there is no basis for measurement of policy impacts (Blandford 2007). This applies for both proactive policies related to technology adoption, as well as reactive policy strategies to respond to extreme conditions. The Nigerian FMARD, donors, and other stakeholders who invest in agricultural production related activities will all benefit from an improved agricultural statistics and information system. Implementation of an agricultural census is a key first step.

In Chapter 3, it was observed that there were broadly long lags in price transmission across all examined markets, although some markets are more interconnected than others. These long lags suggest that prices regularly become disconnected from each other, especially those in isolated rural markets in the short-run, even if they eventually achieve equilibrium. One implication of these long lags in price transmission for food security policy is that trade, especially imports from global markets, are unlikely to be dispersed in a timely enough manner to meet the demand that arises in response to an unexpected production shortfall, especially in isolated rural markets[70]. While trade with neighbor countries was estimated to have, on average, faster price transmission than with global markets, reliance on imports from neighboring countries to meet demand caused by unexpected production shortfalls is infeasible if production conditions in neighbor countries and the affected areas are correlated. This may commonly be the case for markets in Northern Nigeria and its neighbors to the north.

It was also found in Chapter 3 that there are either substantial transactions costs and/or quality premiums that vary with the world price, and/or mark-ups by traders with market power for rice and coarse grains imported from global markets. These large margins were found to apply for coarse grains in Southern Nigeria only, but for rice in all regions. Conversations and limited acquired data in-country suggest that market power among rice traders very likely exists in these markets. Thus, there is opportunity to lower prices if trader margins are cut. Additionally, substantive policy initiatives that reduce overall costs involved in the marketing and trade of imported cereals, and thus, lower barriers to entry, would broadly improve market competition and affordability for consumers and producers that use cereals as inputs.

Due to both long lags in trade from the ports and potentially imperfectly competitive traders that facilitate such imports, it is unlikely that cereals imported from global markets could be imported in a timely or cost-effective manner to meet demand that arises from an unanticipated supply shortage. Thus, some storage facilities are required; either for storage of imports acquired during non-crisis periods or domestically

[70] There is also the issue of whether imported food is a reasonable substitute for food that is presently consumed domestically. This issue is discussed in Chapter 3 and by Minot (2011) with regard to maize. In many SSA countries, white maize is consumed as food, while the vast majority of traded maize is yellow maize used as animal feed.

produced surpluses, for use in occasional disaster responses. Since it was observed that rural areas are relatively less connected to urban markets than urban markets are among themselves, strategic allocation of stored supplies such that they can be made available in the rural areas that are most at risk of growing conditions anomalies as they arise is needed. While the presence of a competitive storage market is typically understood to provide the function of preventing precipitous drops in prices (Wright and Williams 1982), some storage facilities are needed to stabilize prices in short-run response to unexpected spikes (Wright and Williams 1988), if that remains a policy goal of the GON as it was in the wake of the 2007-08 “food crisis” (Olomola 2013).

The GON has been active in building its food storage capacity in recent years, with plans to further expand in the future (FMARD-FSRD). Much of the role of food insecurity response is, however, managed by the ministries of agriculture in individual state governments (NAERLS-NFRA 2009). Thus, development of a feasible and effective strategy that combines the resources of the state and federal government in a manner that positions the stored commodities in locations and at times when food insecurity risk is highest is needed, and will require coordination and sustained cooperation among the state and federal food reserve institutions.

Strategic utilization of existing and planned federal and state government operated emergency food storage facilities would ideally be combined with expanded investments in village level storage infrastructure and improved on-farm storage. Improved local storage remains a key challenge for future development of the Nigerian agricultural system (Okuneye 2002). Larger locally held stocks would reduce the need to meet local supply deficits with outside supplies. Facilitation of better on-farm storage would also provide farmers flexibility to store supplies for later consumption and/or sale at times that best meet their farm profitability and household well-being objectives (Stephens and Barrett 2011). Investment in village level and on-farm storage is, thus, a key component of a comprehensive strategy to allocate food supplies throughout Nigeria in an economically efficient manner.

The results in Chapter 4 showed that, even though growing conditions were found to some substantial degree to explain price variation in local, isolated markets in the short-run, there are other non-weather and non-external price factors that are influential in explaining price variation in these markets. These plausibly relate to transactions costs, since trade from urban to rural markets in Africa is relatively costly compared to trade across urban markets because there is lower quality infrastructure in rural markets (Porteous 2015). Further investigation into the specific transactions cost factors that are most important in prevention or slowing of arbitrage activities to/from rural markets is needed. This would allow for the design of initiatives that address the most critical distortions, and thus, increase interconnectedness of markets and reduce local market price volatility. Targeted rural infrastructure investments will provide similar benefits, and be an important component of a long-run food security strategy in Nigeria.

The finding that other factors than prices in external markets and growing conditions are important for explanation of food prices in local, isolated markets has important implications for future priorities for the WFP and FEWS-NET, as they develop their own strategies to monitor and coordinate responses to intermittent short-run food security disasters in Nigeria and elsewhere. The WFP (and FEWS-NET to a lesser degree) has invested many resources into gathering monthly price data in local markets in many countries (over 80 markets in Niger alone) and reporting them in their VAM Food and Commodity Prices Data Store. The WFP has also investigated investment in a program that would encompass NDVI data into a price forecasting system, but so far appears not to have done so (Brown, Tarnavsky, and Bonifacio 2015). The results from Chapter 4 imply that efforts to supplement price data with such information would be helpful to only a limited degree in Nigerian markets, but may have relatively more explanatory power in areas that have relatively more rainfall variability (such as other countries in the Sahel). More research is needed to inform this debate. The WFP and FEWS-NET would also likely want to consider gathering additional data on other non-price market structural variables that relate to rural market transportation infrastructure after additional studies are implemented that identify the variables on which to focus.

5.3 Recommendations for Future Research

While this dissertation has provided a comprehensive view of the current state of the markets for some of the key crops in Nigeria and the food security implications of how these markets currently operate, there is much work to do in the future that would put Nigeria in a position to develop an effective food policy regime. The first area of recommended focus is on improvement of existing agricultural data gathering systems at the local, state, and national levels. Chapter 2 included some ideas for future research on the viability of a data gathering system that combined use of new remote sensing technology and more costly, but also more reliable, field surveys in order to obtain improved data at an overall lower cost. Since an agricultural census has not been conducted since before the 1980's (Onyeri 2011), implementation of a newly designed data gathering program would in many ways be a start from scratch. The poor quality of agricultural data is, however, implausibly limited to Nigeria[71], so efforts to improve data gathering systems in Nigeria at lower costs would likely have applications in other African countries.

A thorough empirical analysis on the utilization of planned and existing federal and state level food storage facilities that encompasses growing conditions information that identifies the key regions that are at risk of supply shortfalls would be worthwhile. This would ideally be combined with studies of the current capacity and technological status of existing village and on-farm storage infrastructure. These multiple studies could then be combined to determine a comprehensive plan that identifies the most cost-effective and economically efficient strategies to allocate resources in a manner such that they minimize risk of food insecurity risk at the regional and household levels. More complete and updated data on both existing public and private storage capacity and actual held stocks, which would ideally be updated intermittently, would be a pre-requisite for implementation of studies on this issue, as well as for successfully planning targeted interventions to those regions and households with the greatest food insecurity risk.

The persistent concern of funding for implementation and maintenance of improved data gathering systems in Nigeria is likely to persist for some time. Perhaps the most common theme of NAERLS Agricultural Performance Survey reports (e.g.,

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[71] See Jerven 2013 for a discussion of African data in general; and, Kelly and Donovan (2008) for thorough descriptions of data systems in Zambia, Mali, Mozambique, and Rwanda, which are of varying quality but all commonly do not have funds needed to effectively meet data gathering mandates in terms of quality and timeliness.

NAERLS-NFRA 2009), which provide information on overall agricultural production and extension activities in many state ministries of agriculture throughout the country, is how funds for extension activities were either insufficient or not provided at all. These funding issues, however, are not limited to the state governments, but apply to the FMARD as well. One example of resource constraints is the observed withdrawal of FMARD participation in implementation of an agricultural census in Nigeria in 2007 because funds were not allocated for the effort (Onyeri 2011). Detailed analyses on the current organizational and funding structures of agricultural policy institutions in Nigeria, and what those structures mean for institutional capacity and policy implementation would allow for prescription of reforms that could address the persistent funding issue.

If short and long-run food insecurity is to be addressed in an effective manner, it is very likely that some resources will need to be devoted to data collection. Specific public and private sector initiatives that are executed based on rigorous economic analysis and accurate data, and targeted to directly address the most crucial trade and marketing related distortions can plausibly do much to address food insecurity risks and persistent poverty in the future. Successfully addressing these market structure and institutional capacity issues that explain much of the current state of affairs in Nigerian food markets, will not only improve the well-being of current and future Nigerians, but also the livelihoods of people in West Africa and beyond.

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APPENDICES

Appendix 2A: Description of Normalized Difference Vegetation Index (NDVI) Data

The normalized difference vegetation index (NDVI) is an index that measures the "greenness" of a parcel of land by capturing the relative reflectance of red and infrared light from land with different vegetation characteristics (NASA NEO). NDVI data were obtained from the U.S. National Aeronautics and Space Administration (NASA) Earth Observing System Data and Information System (EOSDIS) "Reverb" website[72]. There were essentially 5 steps implemented to obtain the NDVI data for use in empirical analyses.

The first step was to download the raw satellite pictures from the NASA Reverb website. Based on information in the literature (e.g., Brown and Kshirsagar 2015) and conversations with experts in the remote sensing field, data from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the Aqua satellite were acquired. The Reverb system allows for searching by the type of data that one wishes to acquire. In this case, it was NDVI data, projected onto a Climate Modeling Grid (CMG) that links the satellite data to geographic locations throughout the globe. Thus, a search was done on the Reverb website for "MODIS NDVI CMG". Monthly (rather than 16-day) images were selected because these align with the observations of the matched price data. The name of the data product for the monthly vegetation index with satellite data projected onto a global map is "MYD13C2", version 6 (V006). Within this data product, any data interference due to cloud contamination is dealt with through replacement of cloud contaminated observation measures with measures that are consistent with historical time series values (USGS 2014). After the desired satellite vegetation data were found, these were downloaded for the period January 2001-December 2010. This period was chosen because that is the period for which Nigerian price data, also used in the analysis, were available.

The second step involved acquisition of the tool capable of conversion of data from Hierarchical Data Format of the Earth Observation System (HDF-EOS), the standard form for NASA satellite data, to GeoTiff (.tif) format to allow for use in

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[72] Website address is:
http://reverb.echo.nasa.gov/reverb/#utf8=%E2%9C%93&spatial_map=satellite&spatial_type=rectangle.

ArcMap. To do this, the HDF-EOS to GeoTiff Conversion Tool (HEG) was downloaded from the NASA HEG website[73].

In the third step, this HEG tool was used to convert each HDF-EOS file to GeoTiff files. The MYD13C2 dataset includes multiple vegetation index measures, so within the HEG tool, NDVI was selected in the drop down menu out of the handful of possible options. The default pixel size of 5,600 square meters was used. The result after this fourth step was acquisition of a set of 120 satellite pictures of the earth (in GeoTiff file form) with NDVI measures embedded with associated geographic information (e.g., spatial coordinates).

In the fourth step, the desired areas of observation in Nigeria were chosen. It was decided that it would be desirable to mask out as much non-cropland area as possible in order to obtain the most representative vegetation for agricultural production in Nigeria. This led to the search for a "cropland" mask that could isolate cropland on maps in ArcMap. To do this, a cropland mask GeoTiff file specific to Nigeria was obtained from the Africa Soil Information Service (AfSIS). This cropland mask excludes urban and heavily wooded areas. The study areas were the entire country, Northern Nigeria; Kano, Katsina, Niger, and Borno states; and, local areas around the towns of Damasak, Borno, Jibia, Katsina, and Daura, Katsina. Northern Nigeria was a key focus region because the examined crops are primarily grown in the north (FEWS-NET 2014). Also, annual rainfall is more variable in the north than the south (Aregheore 2005), which means there is less likelihood of NDVI data sampling bias due to cloud contamination for Northern Nigeria. Administrative borders for Nigeria and its states were obtained from the DIVA-GIS website[74]. The Northern Nigeria region was isolated through selection of the states in the North Central, Northwest, and Northeast zones, as defined in the NBS "Basic Information Document" associated with the 2010-11 General Household Survey (NBS 2015), into a Northern Nigeria mask composed of an aggregate of state borders in these regions.

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[73] Website address is: http://newsroom.gsfc.nasa.gov/sdptoolkit/HEG/HEGDownload.html.
[74] The DIVA-GIS website is maintained by LizardTech Inc. and the University of California. The website address is: http://www.diva-gis.org/Data.

The final implementation steps were completed within ArcMap. These steps were: 1) cropland masks for the relevant Northern Nigeria region and select individual states were constructed through combination of the AfSIS cropland mask and the administrative border files from DIVA-GIS; 2) the NDVI data were extracted from the GeoTiff files with the NDVI measures for the relevant croplands for each month over the period January 2001-December 2010; 3) the “Zonal Statistics” tool in ArcMap was used to calculate the average NDVI value for each month across each of the analyzed regions; and, lastly, 4) each monthly spatially averaged NDVI value was combined to form a time series of NDVI values for each month such that it could be organized for analysis in standard statistical analysis software programs (e.g., Excel and STATA).

Appendix 2B: Comprehensive Results for the Estimated Correlation of Crop Production and Yield with NDVI Data for Kano, Katsina, Niger, and Borno states

Table 2B-1: Correlation coefficients for estimates of crop production and yield with NDVI data for Kano State for the period 2001-10

	Production			Yield		
Maize	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	0.68	-0.90	-0.93	-0.85	-0.83	…
GS Avg. NDVI	0.64	-0.58	-0.89	-0.82	-0.83	…
Peak mo. NDVI value	0.03	-0.22	-0.57	-0.17	-0.04	…
NDVI val. of month w/ max anomalies	0.45	-0.63	-0.65	-0.75	-0.76	…
Rice	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	-0.28	-0.81	-0.65	-0.78	-0.77	…
GS Avg. NDVI	-0.26	-0.32	-0.58	-0.76	-0.75	…
Peak mo. NDVI value	0.43	-0.09	-0.35	-0.23	0	…
NDVI val. of month w/ max anomalies	-0.47	-0.68	-0.37	-0.62	-0.53	…
Millet	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	0.13	-0.61	-0.13	-0.50	-0.64	…
GS Avg. NDVI	0.08	-0.14	0.04	-0.45	-0.60	…
Peak mo. NDVI value	0.47	0.07	-0.20	-0.20	0.07	…
NDVI val. of month w/ max anomalies	0.12	-0.46	0.22	-0.17	-0.59	…
Sorghum	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	-0.17	-0.68	-0.70	-0.28	-0.37	…
GS Avg. NDVI	-0.20	-0.24	-0.62	-0.21	-0.35	…
Peak mo. NDVI value	0.47	-0.04	-0.30	-0.51	0.28	…
NDVI val. of month w/ max anomalies	-0.35	-0.46	-0.53	0.28	-0.29	…
Cowpeas	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	0.49	0.81	-0.06	-0.37	-0.72	…
GS Avg. NDVI	0.34	0.74	0.08	-0.32	-0.66	…
Peak mo. NDVI value	0.36	0.54	-0.32	0.19	-0.17	…
NDVI val. of month w/ max anomalies	0.27	0.53	0.30	-0.43	-0.33	…
Cassava	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	-0.58	-0.37	-0.52	0.77	-0.06	…
GS Avg. NDVI	-0.57	-0.32	-0.49	0.79	-0.08	…
Peak mo. NDVI value	0.12	0.13	-0.27	0.66	-0.65	…
NDVI val. of month w/ max anomalies	-0.55	-0.19	-0.32	0.50	0.38	…
Yams	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	…	…	…	…	…	…
GS Avg. NDVI	…	…	…	…	…	…
Peak mo. NDVI value	…	…	…	…	…	…
NDVI val. of month w/ max anomalies	…	…	…	…	…	…

Note: NDVI is the normalized difference vegetation index; GS is the abbreviation for “growing season”; “peak mo.” is the month with the highest average NDVI values of all months, averaged across the observation period of January 2001 to December 2010; and, the “NDVI val. of month w/ max anomalies” is the NDVI value associated with the month in which the most NDVI anomalies were observed. A positive sign is expected for all correlation estimates.

Table 2B-2: Correlation coefficients for estimates of crop production and yield with NDVI data for Katsina State for the period 2001-10

	Production			Yield		
Maize	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	0.03	-0.64	…	-0.59	-0.67	…
GS Avg. NDVI	0.04	-0.57	…	-0.59	-0.63	…
Peak mo. NDVI value	0.57	-0.36	…	-0.19	-0.38	…
NDVI val. of month w/ max anomalies	0.15	-0.49	…	-0.05	-0.57	…
Rice	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	0.22	-0.81	…	0.15	-0.68	…
GS Avg. NDVI	0.16	-0.78	…	0.26	-0.61	…
Peak mo. NDVI value	0.58	-0.51	…	0.31	-0.42	…
NDVI val. of month w/ max anomalies	0.41	-0.62	…	0.09	-0.67	…
Millet	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	-0.29	-0.53	…	-0.70	-0.41	…
GS Avg. NDVI	-0.29	-0.48	…	-0.71	-0.37	…
Peak mo. NDVI value	0.18	-0.33	…	-0.33	-0.22	…
NDVI val. of month w/ max anomalies	-0.19	-0.44	…	-0.38	-0.39	…
Sorghum	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	-0.20	-0.86	…	-0.82	-0.03	…
GS Avg. NDVI	-0.14	-0.84	…	-0.83	-0.20	…
Peak mo. NDVI value	0.33	-0.64	…	-0.39	0.30	…
NDVI val. of month w/ max anomalies	-0.19	-0.46	…	-0.26	-0.20	…
Cowpeas	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	0.27	-0.31	…	-0.16	0.45	…
GS Avg. NDVI	0.29	-0.42	…	-0.17	0.31	…
Peak mo. NDVI value	0.65	0.16	…	-0.11	0.98	…
NDVI val. of month w/ max anomalies	0.24	-0.03	…	-0.04	0.99	…
Cassava	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	…	-0.33	…	…	-0.34	…
GS Avg. NDVI	…	-0.28	…	…	-0.41	…
Peak mo. NDVI value	…	0.14	…	…	-0.22	…
NDVI val. of month w/ max anomalies	…	-0.20	…	…	-0.29	…
Yams	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	…	0.49	…	…	-0.90	…
GS Avg. NDVI	…	0.54	…	…	-0.90	…
Peak mo. NDVI value	…	0.84	…	…	-0.99	…
NDVI val. of month w/ max anomalies	…	0.35	…	…	-0.93	…

Note: a description of the abbreviations of the NDVI measures is included below table 2B-1.

Table 2B-3: Correlation coefficients for estimates of crop production and yield with NDVI data for Niger State for the period 2001-10

	Production			Yield		
Maize	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	-0.27	0.12	0.11	-0.30	-0.06	-0.78
GS Avg. NDVI	-0.87	-0.21	-0.25	-0.79	-0.38	-0.56
Peak mo. NDVI value	-0.63	-0.10	-0.10	-0.57	-0.35	-0.48
NDVI val. of month w/ max anomalies	-0.20	0.45	0.42	-0.06	0.37	0.08
Rice	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	-0.00	-0.21	-0.24	0.22	0.06	-0.34
GS Avg. NDVI	-0.30	-0.12	-0.14	0.51	-0.24	-0.48
Peak mo. NDVI value	-0.39	-0.41	-0.31	0.44	0.10	-0.22
NDVI val. of month w/ max anomalies	0.30	0.61	0.28	-0.04	0.22	-0.14
Millet	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	0.46	0.30	0.27	0.36	0.16	-0.23
GS Avg. NDVI	0.30	-0.29	-0.31	0.23	-0.27	-0.62
Peak mo. NDVI value	0.04	0.02	-0.03	-0.06	-0.17	-0.34
NDVI val. of month w/ max anomalies	0.04	-0.11	-0.09	0.27	0.13	0.06
Sorghum	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	0.09	-0.49	-0.09	0.07	-0.63	-0.12
GS Avg. NDVI	-0.42	-0.58	-0.50	0.04	-0.65	-0.11
Peak mo. NDVI value	-0.26	-0.68	-0.18	-0.30	-0.65	-0.54
NDVI val. of month w/ max anomalies	-0.40	0.08	0.03	0.09	-0.21	0.38
Cowpeas	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	0.49	0.53	-0.06	0.35	-0.05	-0.16
GS Avg. NDVI	0.22	0.35	0.05	0.70	-0.30	-0.41
Peak mo. NDVI value	0.05	0.44	-0.36	0.18	0.06	-0.15
NDVI val. of month w/ max anomalies	0.36	-0.27	0.11	0.65	-0.24	-0.63
Cassava	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	0.01	-0.28	0.02	0	-0.03	0.67
GS Avg. NDVI	-0.36	-0.33	-0.27	-0.31	-0.28	0.71
Peak mo. NDVI value	-0.40	-0.42	-0.19	-0.37	-0.07	0.48
NDVI val. of month w/ max anomalies	0.20	0.45	0.17	0.39	0.31	0.11
Yams	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	-0.13	-0.37	-0.30	0.01	-0.09	0.06
GS Avg. NDVI	-0.37	-0.42	-0.33	-0.11	-0.14	0.02
Peak mo. NDVI value	-0.71	-0.44	-0.50	-0.18	-0.20	-0.44
NDVI val. of month w/ max anomalies	0.41	0.35	0.54	-0.34	0.53	0.55

Note: a description of the abbreviations of the NDVI measures is included below table 2B-1.

Table 2B-4: Correlation coefficients for estimates of crop production and yield with NDVI data for Borno State for the period 2001-10

	Production			Yield		
Maize	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	0.14	0.23	…	-0.13	0.20	…
GS Avg. NDVI	-0.04	0.04	…	-0.28	0.01	…
Peak mo. NDVI value	-0.16	0.03	…	-0.25	0.07	…
NDVI val. of month w/ max anomalies	-0.14	-0.23	…	-0.34	-0.23	…
Rice	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	-0.03	-0.17	…	0.38	-0.17	…
GS Avg. NDVI	-0.08	-0.20	…	0.19	0	…
Peak mo. NDVI value	0.07	-0.50	…	0.29	-0.12	…
NDVI val. of month w/ max anomalies	-0.16	-0.10	…	-0.21	0.27	…
Millet	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	-0.05	-0.43	…	0	0	…
GS Avg. NDVI	-0.24	-0.35	…	-0.12	-0.17	…
Peak mo. NDVI value	-0.29	-0.24	…	-0.16	-0.14	…
NDVI val. of month w/ max anomalies	-0.30	-0.15	…	-0.21	-0.34	…
Sorghum	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	0.19	0.20	…	0	0.14	…
GS Avg. NDVI	-0.01	0.02	…	-0.19	-0.05	…
Peak mo. NDVI value	-0.12	0.05	…	-0.01	0.13	…
NDVI val. of month w/ max anomalies	-0.15	-0.28	…	-0.34	-0.33	…
Cowpeas	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	0.04	0.27	…	-0.04	0.91	…
GS Avg. NDVI	-0.16	0.13	…	-0.17	0.97	…
Peak mo. NDVI value	-0.30	0.10	…	-0.24	0.94	…
NDVI val. of month w/ max anomalies	-0.19	-0.10	…	-0.15	0.88	…
Cassava	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	…	0.15	…	…	0.23	…
GS Avg. NDVI	…	0.26	…	…	0.20	…
Peak mo. NDVI value	…	0.22	…	…	-0.28	…
NDVI val. of month w/ max anomalies	…	0.30	…	…	0.30	…
Yams	NBS	NPAFS	ADP	NBS	NPAFS	ADP
Annual Avg. NDVI	…	…	…	…	…	…
GS Avg. NDVI	…	…	…	…	…	…
Peak mo. NDVI value	…	…	…	…	…	…
NDVI val. of month w/ max anomalies	…	…	…	…	…	…

Note: a description of the abbreviations of the NDVI measures is included below table 2B-1.

Appendix 2C: Comprehensive Results for the Estimated Correlation of Crop Production with Urban and Rural Harvest Month Prices for Kano, Katsina, Niger, and Borno states

Table 2C-1: Correlation coefficients for production in Kano State with urban prices for the period 2001-10 and rural prices for the period 2007-10

	Urban prices			Rural prices		
NBS	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Maize	-0.20	-0.33	-0.48	0.07	0.22	0.24
Local rice	0.83	0.86	0.87	0.84	0.83	0.73
Imported rice	0.81	0.83	0.82	0.92	0.86	0.84
Millet	0.13	0.28	0.33	0.31	0.86	0.73
Sorghum	0.68	0.50	0.54	0.30	0.17	0.54
Cowpeas	-0.50	-0.41	-0.43	0.72	0.84	0.42
Cassava	0.62	0.85	0.83	0.92	0.94	0.92
Yams	…	…	…	…	…	…
NPAFS	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Maize	0.69	0.57	0.63	0.48	0.25	0.49
Local rice	0.76	0.76	0.83	0.98	0.99	0.99
Imported rice	0.73	0.74	0.76	0.90	1	0.98
Millet	0.44	0.78	0.63	0.50	0.94	0.97
Sorghum	0.41	0.28	0.76	-0.11	0.61	0.21
Cowpeas	-0.48	-0.36	-0.47	0.67	-0.03	0.28
Cassava	0.74	0.57	0.54	-0.46	-0.50	-0.45
Yams	…	…	…	…	…	…
ADP	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Maize	0.78	0.59	0.63	0.69	0.48	0.70
Local rice	0.89	0.90	0.92	0.78	0.94	0.95
Imported rice	0.86	0.90	0.91	0.60	0.92	0.78
Millet	0.44	0.58	0.58	-0.12	0.54	0.64
Sorghum	0.46	0.34	0.77	-0.10	0.61	0.21
Cowpeas	0.18	0.28	0.38	0.88	0.96	1
Cassava	0.77	0.60	0.57	-0.24	-0.29	-0.24
Yams	…	…	…	…	…	…

Table 2C-2: Correlation coefficients for production in Katsina State with urban prices for the period 2001-10 and rural prices for the period 2007-10

	Urban prices			Rural prices		
NBS	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Maize	0.67	0.64	0.60	0.26	0.68	0.55
Local rice	0.10	0.07	0.20	-0.24	-0.08	-0.25
Imported rice	0.15	0.18	0.16	0.28	0.55	0.37
Millet	0.91	0.83	0.53	0.47	0.48	0.12
Sorghum	0.82	0.56	0.70	0.15	0.57	0.90
Cowpeas	0.69	0.55	0.58	0.50	0.49	0.45
Cassava	…	…	…	…	…	…
Yams	…	…	…	…	…	…
NPAFS	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Maize	0.88	0.82	0.84	0.96	0.94	0.91
Local rice	0.81	0.82	0.94	0.68	0.61	0.69
Imported rice	0.84	0.86	0.88	-0.02	-0.10	0.05
Millet	0.80	0.92	0.75	0.69	0.70	0.40
Sorghum	0.78	0.68	0.81	0.93	1	0.92
Cowpeas	0.48	0.47	0.54	0.64	0.76	0.60
Cassava	0.83	0.84	0.85	0.98	0.81	0.97
Yams	…	…	…	…	…	…

Table 2C-3: Correlation coefficients for production in Borno State with urban prices for the period 2001-10 and rural prices for the period 2007-10

	Urban prices			Rural prices		
NBS	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Maize	0.61	0.45	0.52	-0.15	0.86	0.86
Local rice	0.87	0.93	0.92	-0.12	0.77	0.56
Imported rice	0.91	0.94	0.93	0.83	0.54	0.60
Millet	0.54	0.64	0.66	0.72	0.23	0.34
Sorghum	0.47	0.52	0.51	0.03	0.80	0.13
Cowpeas	0.21	0.14	0.37	0.77	0.76	0.61
Cassava	…	…	…	…	…	…
Yams	…	…	…	…	…	…
NPAFS	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Maize	0.64	0.52	0.54	0.10	0.94	0.96
Local rice	0.59	0.62	0.62	0.40	0.96	0.92
Imported rice	0.65	0.62	0.76	0.94	0.83	0.89
Millet	-0.40	-0.40	-0.48	0.33	0.90	0.84
Sorghum	0.65	0.76	0.78	0.34	0.88	0.46
Cowpeas	0.63	0.62	0.64	0.60	0.60	0.50
Cassava	-0.34	-0.73	-0.71	-0.51	-0.24	-0.40
Yams	…	…	…	…	…	…

Table 2C-4: Correlation coefficients for production in Niger State with urban prices for the period 2001-10 and rural prices for the period 2007-10

	Urban prices			Rural prices		
NBS	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Maize	0.61	0.72	0.28	0.76	0.84	0.30
Local rice	0.73	0.81	0.62	-0.67	-0.23	0.11
Imported rice	0.80	0.68	0.67	-0.19	-0.57	-0.10
Millet	-0.29	-0.49	-0.50	-0.55	-0.48	-0.70
Sorghum	-0.03	-0.15	-0.29	0.19	-0.35	-0.42
Cowpeas	0.03	-0.15	-0.17	-0.36	-0.30	-0.53
Cassava	0.63	0.68	0.68	0.46	0.64	0.72
Yams	0.13	-0.13	0.06	0.69	0.21	0.79
NPAFS	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Maize	0.53	0.64	0.59	0.95	1	0.99
Local rice	0.73	0.76	0.84	1	0.97	0.77
Imported rice	0.75	0.81	0.82	1	0.98	0.93
Millet	0.41	0.55	0.46	0.69	0.72	0.48
Sorghum	-0.05	0.10	0.29	0.64	0.42	0.64
Cowpeas	-0.29	-0.49	-0.50	0.76	0.79	0.75
Cassava	0.41	0.64	0.61	0.95	0.76	0.65
Yams	0.71	0.70	0.86	0.64	-0.63	0.87
ADP	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Maize	0.53	0.64	0.58	0.95	1	0.99
Local rice	0.65	0.79	0.78	1	0.97	0.77
Imported rice	0.65	0.78	0.77	1	0.98	0.93
Millet	0.42	0.54	0.46	0.69	0.72	0.48
Sorghum	0.26	0.35	0.43	0.10	-0.16	0.10
Cowpeas	-0.32	-0.28	-0.29	0.90	0.92	0.90
Cassava	0.20	0.47	0.51	0.78	0.47	0.33
Yams	0.78	0.70	0.90	0.81	-0.80	0.96

Appendix 2D: Comprehensive Results for the Estimated Correlation of NDVI Data with Urban and Rural Harvest Month Prices for Kano, Katsina, Niger, and Borno states

Table 2D-1: Correlation coefficients for NDVI data for Kano State and Northern Nigeria with urban harvest month prices for the period 2001-10

	NDVI state			NDVI Northern Nigeria		
Maize	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.31	-0.14	-0.30	-0.34	-0.10	-0.16
GS Avg. NDVI	-0.29	-0.10	-0.19	-0.75	-0.48	-0.27
Peak mo. NDVI value	0.33	0.62	0.39	-0.66	-0.42	-0.20
NDVI val. of month w/ max anomalies	-0.41	-0.40	-0.26	-0.58	-0.31	-0.13
Local rice	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.18	-0.16	-0.25	-0.06	-0.05	-0.02
GS Avg. NDVI	-0.09	-0.08	-0.12	-0.42	-0.43	-0.35
Peak mo. NDVI value	0.46	0.51	0.43	-0.39	-0.35	-0.19
NDVI val. of month w/ max anomalies	-0.15	-0.14	-0.18	-0.13	-0.15	-0.12
Imported rice	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.21	-0.15	-0.18	-0.03	0.03	0.05
GS Avg. NDVI	-0.11	-0.05	-0.08	-0.35	-0.33	-0.31
Peak mo. NDVI value	0.47	0.51	0.49	-0.35	-0.30	-0.29
NDVI val. of month w/ max anomalies	-0.21	-0.13	-0.16	-0.11	-0.07	-0.05
Millet	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.03	-0.23	-0.25	0.01	-0.07	-0.11
GS Avg. NDVI	0.05	-0.16	-0.15	-0.14	-0.41	-0.14
Peak mo. NDVI value	0.44	0.53	0.33	-0.17	-0.38	-0.22
NDVI val. of month w/ max anomalies	-0.22	-0.42	-0.22	-0.09	-0.25	-0.02
Sorghum	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.14	-0.08	-0.58	-0.13	-0.08	-0.43
GS Avg. NDVI	-0.18	-0.06	-0.48	-0.54	-0.27	-0.46
Peak mo. NDVI value	0.58	0.54	0.12	-0.58	-0.28	-0.41
NDVI val. of month w/ max anomalies	-0.60	-0.41	-0.40	-0.48	-0.24	-0.32
Cowpeas	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.62	-0.50	-0.64	-0.43	-0.41	-0.42
GS Avg. NDVI	-0.54	-0.43	-0.56	-0.51	-0.44	-0.46
Peak mo. NDVI value	0.09	0.19	0.04	-0.32	-0.30	-0.34
NDVI val. of month w/ max anomalies	-0.57	-0.53	-0.58	-0.31	-0.17	-0.20
Cassava	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.07	-0.15	-0.25	-0.09	-0.10	-0.14
GS Avg. NDVI	-0.02	-0.11	-0.22	-0.45	-0.55	-0.57
Peak mo. NDVI value	0.42	0.48	0.45	-0.37	-0.41	-0.50
NDVI val. of month w/ max anomalies	-0.22	-0.36	-0.49	-0.34	-0.39	-0.43
Yams	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.32	-0.11	-0.03	-0.10	0.11	0.35
GS Avg. NDVI	-0.25	-0.09	0.03	-0.55	-0.47	-0.34
Peak mo. NDVI value	0.42	0.58	0.59	-0.32	-0.37	-0.36
NDVI val. of month w/ max anomalies	-0.32	-0.26	-0.19	-0.37	-0.31	-0.18

Note: a description of the abbreviations of the NDVI measures is included below table 2B-1.

Table 2D-2: Correlation coefficients for NDVI data for Kano State and Northern Nigeria with Kano State rural harvest month prices for the period 2007-10

	NDVI state			NDVI Northern Nigeria		
Maize	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.09	0.13	0.07	0.01	0.29	0.11
GS Avg. NDVI	-0.15	0.08	0	-0.82	-0.75	-0.89
Peak mo. NDVI value	0.47	0.63	0.61	-0.99	-0.97	-0.99
NDVI val. of month w/ max anomalies	-0.79	-0.60	-0.70	-0.84	-0.90	-0.92
Local rice	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.21	0.55	0.41	0.28	0.63	0.58
GS Avg. NDVI	0.15	0.50	0.37	-0.84	-0.69	-0.64
Peak mo. NDVI value	0.71	0.89	0.79	-0.97	-0.80	-0.85
NDVI val. of month w/ max anomalies	-0.56	-0.22	-0.32	-0.96	-0.96	-0.92
Imported rice	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.19	0.55	0.21	0.14	0.61	0.28
GS Avg. NDVI	0.11	0.50	0.15	-0.95	-0.73	-0.84
Peak mo. NDVI value	0.70	0.90	0.71	-0.95	-0.80	-0.97
NDVI val. of month w/ max anomalies	-0.61	-0.22	-0.58	-0.96	-0.97	-0.96
Millet	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.14	0.06	0.38	0.15	0.40	0.66
GS Avg. NDVI	0.07	0.04	0.36	-0.91	-0.37	-0.38
Peak mo. NDVI value	0.67	0.44	0.66	-0.98	-0.79	-0.71
NDVI val. of month w/ max anomalies	-0.65	-0.46	-0.20	-0.95	-0.67	-0.75
Sorghum	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.38	-0.17	-0.02	-0.44	0.08	-0.03
GS Avg. NDVI	-0.46	-0.21	-0.10	-0.85	-0.60	-0.93
Peak mo. NDVI value	0.18	0.35	0.54	-0.86	-0.94	-0.98
NDVI val. of month w/ max anomalies	-0.93	-0.76	-0.76	-0.62	-0.72	-0.88
Cowpeas	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.12	-0.14	-0.54	-0.14	-0.24	-0.64
GS Avg. NDVI	-0.19	0.06	-0.61	-0.92	-0.87	-0.75
Peak mo. NDVI value	0.45	0.46	-0.03	-0.96	-0.47	-0.71
NDVI val. of month w/ max anomalies	-0.82	-0.38	-0.93	-0.83	-0.58	-0.42
Cassava	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.64	0.65	0.60	0.59	0.62	0.57
GS Avg. NDVI	0.58	0.59	0.54	-0.78	-0.76	-0.79
Peak mo. NDVI value	0.96	0.96	0.94	-0.74	-0.74	-0.78
NDVI val. of month w/ max anomalies	-0.15	-0.14	-0.20	-0.97	-0.97	-0.98
Yams	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.95	0.57	0.96	0.81	0.45	0.82
GS Avg. NDVI	0.97	0.51	0.93	0.11	-0.88	-0.42
Peak mo. NDVI value	0.62	0.93	0.95	0.35	-0.75	-0.22
NDVI val. of month w/ max anomalies	-0.86	-0.23	0.43	-0.15	-0.97	-0.67

Note: a description of the abbreviations of the NDVI measures is included below table 2B-1.

Table 2D-3: Correlation coefficients for NDVI data for Katsina State and Northern Nigeria with Katsina State urban harvest month prices for the period 2001-10

	NDVI state			NDVI Northern Nigeria		
Maize	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.50	-0.40	-0.53	-0.46	-0.33	-0.43
GS Avg. NDVI	-0.47	-0.37	-0.47	-0.64	-0.54	-0.53
Peak mo. NDVI value	-0.01	-0.05	-0.16	-0.56	-0.61	-0.49
NDVI val. of month w/ max anomalies	-0.25	-0.12	-0.30	-0.44	-0.37	-0.37
Local rice	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.28	-0.31	-0.48	-0.11	-0.18	-0.23
GS Avg. NDVI	-0.20	-0.19	-0.41	-0.40	-0.40	-0.45
Peak mo. NDVI value	0.10	0.06	-0.05	-0.44	-0.37	-0.38
NDVI val. of month w/ max anomalies	-0.24	-0.35	-0.39	-0.12	-0.07	-0.21
Imported rice	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.29	-0.29	-0.36	-0.16	-0.14	-0.18
GS Avg. NDVI	-0.21	-0.21	-0.27	-0.47	-0.45	-0.40
Peak mo. NDVI value	0.11	0.14	0.06	-0.47	-0.41	-0.33
NDVI val. of month w/ max anomalies	-0.27	-0.25	-0.33	-0.16	-0.15	-0.11
Millet	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.37	-0.26	-0.28	-0.35	-0.19	-0.05
GS Avg. NDVI	-0.32	-0.17	-0.13	-0.70	-0.58	-0.13
Peak mo. NDVI value	0.12	0.14	-0.01	-0.54	-0.53	-0.18
NDVI val. of month w/ max anomalies	-0.22	-0.16	-0.17	-0.58	-0.40	-0.04
Sorghum	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.32	-0.30	-0.52	-0.38	-0.20	-0.34
GS Avg. NDVI	-0.26	-0.24	-0.47	-0.61	-0.35	-0.51
Peak mo. NDVI value	0.23	0.02	-0.14	-0.41	-0.42	-0.48
NDVI val. of month w/ max anomalies	-0.11	-0.05	-0.31	-0.46	-0.24	-0.33
Cowpeas	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.36	-0.37	-0.51	-0.41	-0.30	-0.43
GS Avg. NDVI	-0.29	-0.29	-0.43	-0.71	-0.50	-0.62
Peak mo. NDVI value	0.12	0.03	0.01	-0.56	-0.42	-0.41
NDVI val. of month w/ max anomalies	-0.25	-0.21	-0.39	-0.46	-0.31	-0.37
Cassava	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.01	0.02	-0.05	-0.06	-0.04	-0.12
GS Avg. NDVI	0.06	0.09	0.02	-0.49	-0.49	-0.54
Peak mo. NDVI value	0.46	0.52	0.45	-0.37	-0.33	-0.38
NDVI val. of month w/ max anomalies	0.07	0.09	0.04	-0.38	-0.35	-0.40
Yams	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.39	-0.37	-0.50	-0.14	-0.17	-0.16
GS Avg. NDVI	-0.27	-0.31	-0.42	-0.22	-0.42	-0.30
Peak mo. NDVI value	0.03	0.17	-0.03	-0.04	-0.11	-0.11
NDVI val. of month w/ max anomalies	-0.46	-0.36	-0.48	0.04	-0.22	-0.08

Note: a description of the abbreviations of the NDVI measures is included below table 2B-1.

Table 2D-4: Correlation coefficients for NDVI data for Katsina State and Northern Nigeria with Katsina State rural harvest month prices for the period 2007-10

	NDVI state			NDVI Northern Nigeria		
Maize	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.46	0.17	0.06	-0.63	0.09	0.06
GS Avg. NDVI	-0.50	0.13	0.01	-0.67	-0.83	-0.72
Peak mo. NDVI value	-0.29	0.20	0.05	-0.74	-1	-0.98
NDVI val. of month w/ max anomalies	0	0.54	0.40	-0.40	-0.88	-0.80
Local rice	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.16	0	-0.17	-0.49	-0.34	-0.50
GS Avg. NDVI	-0.20	-0.05	-0.21	-0.88	-0.94	-0.87
Peak mo. NDVI value	0.06	0.20	0.05	-0.78	-0.83	-0.76
NDVI val. of month w/ max anomalies	0.33	0.47	0.32	-0.59	-0.71	-0.58
Imported rice	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.24	0.53	0.36	0.17	0.41	0.22
GS Avg. NDVI	0.20	0.49	0.32	-0.82	-0.83	-0.89
Peak mo. NDVI value	0.25	0.53	0.40	-0.99	-0.91	-0.97
NDVI val. of month w/ max anomalies	0.58	0.80	0.70	-0.90	-0.99	-0.96
Millet	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.02	0.09	0.40	-0.21	-0.16	-0.05
GS Avg. NDVI	-0.02	0.04	0.36	-0.92	-0.95	-0.97
Peak mo. NDVI value	0.25	0.53	0.61	-0.94	-0.94	-0.68
NDVI val. of month w/ max anomalies	0.58	0.80	0.70	-0.90	-0.99	-0.96
Sorghum	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.47	0.04	0.46	-0.69	-0.18	0
GS Avg. NDVI	-0.51	-0.01	0.42	-0.67	-0.92	-0.95
Peak mo. NDVI value	-0.28	0.16	0.67	-0.68	-0.96	-0.63
NDVI val. of month w/ max anomalies	0	0.49	0.80	-0.35	-0.81	-0.78
Cowpeas	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.26	0.21	0.21	-0.06	-0.02	-0.12
GS Avg. NDVI	0.21	0.16	0.16	-0.99	-0.95	-0.99
Peak mo. NDVI value	0.41	0.31	0.37	-0.90	-0.97	-0.89
NDVI val. of month w/ max anomalies	0.68	0.62	0.64	-0.88	-0.90	-0.85
Cassava	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.73	0.97	0.78	0.57	0.82	0.62
GS Avg. NDVI	0.70	0.96	0.75	-0.79	-0.50	-0.76
Peak mo. NDVI value	0.73	0.93	0.77	-0.78	-0.36	-0.73
NDVI val. of month w/ max anomalies	0.92	0.95	0.94	-0.98	-0.77	-0.97
Yams	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.10	0.73	0.80	-0.06	0.85	0.98
GS Avg. NDVI	0.05	0.72	0.80	-0.89	-0.36	-0.08
Peak mo. NDVI value	0.18	0.57	0.59	-0.99	-0.56	-0.24
NDVI val. of month w/ max anomalies	0.52	0.70	0.61	-0.85	-0.76	-0.54

Note: a description of the abbreviations of the NDVI measures is included below table 2B-1.

Table 2D-5: Correlation coefficients for NDVI data for Niger State and Northern Nigeria with Niger State urban harvest month prices for the period 2001-10

	NDVI state			NDVI Northern Nigeria		
Maize	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.07	0.14	0.15	0.08	0.24	0
GS Avg. NDVI	-0.48	-0.56	-0.21	-0.32	-0.32	-0.13
Peak mo. NDVI value	-0.17	-0.31	-0.19	-0.34	-0.29	-0.21
NDVI val. of month w/ max anomalies	0.06	0	0.02	-0.25	-0.24	-0.09
Local rice	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.14	-0.13	-0.07	-0.20	-0.12	-0.10
GS Avg. NDVI	-0.34	-0.53	-0.33	-0.53	-0.58	-0.35
Peak mo. NDVI value	-0.47	-0.55	-0.28	-0.48	-0.46	-0.30
NDVI val. of month w/ max anomalies	0.52	0.31	0.36	-0.22	-0.29	-0.05
Imported rice	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.13	-0.18	-0.15	-0.13	-0.20	-0.13
GS Avg. NDVI	-0.46	-0.42	-0.37	-0.55	-0.50	-0.39
Peak mo. NDVI value	-0.47	-0.36	-0.30	-0.46	-0.41	-0.29
NDVI val. of month w/ max anomalies	0.40	0.35	0.36	-0.28	-0.20	-0.08
Millet	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.19	0.16	0.28	-0.07	-0.15	-0.15
GS Avg. NDVI	-0.35	-0.32	-0.11	-0.33	-0.34	-0.27
Peak mo. NDVI value	-0.06	0.02	-0.06	-0.37	-0.38	-0.29
NDVI val. of month w/ max anomalies	0.13	0.06	0.43	-0.35	-0.34	-0.18
Sorghum	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.23	-0.36	-0.39	-0.25	-0.33	-0.52
GS Avg. NDVI	-0.44	-0.52	-0.47	-0.33	-0.41	-0.63
Peak mo. NDVI value	-0.07	-0.13	-0.38	-0.30	-0.36	-0.56
NDVI val. of month w/ max anomalies	-0.02	-0.04	0.33	-0.28	-0.29	-0.39
Cowpeas	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.11	-0.33	-0.27	-0.17	-0.36	-0.28
GS Avg. NDVI	-0.44	-0.60	-0.50	-0.44	-0.65	-0.50
Peak mo. NDVI value	-0.33	-0.51	-0.42	-0.40	-0.57	-0.40
NDVI val. of month w/ max anomalies	0.33	0.23	0.29	-0.23	-0.39	-0.25
Cassava	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.06	-0.10	-0.19	0.04	0.07	-0.09
GS Avg. NDVI	-0.55	-0.65	-0.75	-0.36	-0.43	-0.59
Peak mo. NDVI value	-0.42	-0.45	-0.49	-0.29	-0.33	-0.48
NDVI val. of month w/ max anomalies	0.18	0.13	0.03	-0.25	-0.29	-0.48
Yams	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.02	0.03	-0.28	-0.31	0.52	-0.07
GS Avg. NDVI	-0.32	-0.01	-0.48	-0.99	0.49	-0.93
Peak mo. NDVI value	-0.37	0.07	-0.51	-0.84	-0.05	-0.73
NDVI val. of month w/ max anomalies	-0.03	0.21	-0.21	-0.90	-0.73	-0.81

Note: a description of the abbreviations of the NDVI measures is included below table 2B-1.

Table 2D-6: Correlation coefficients for NDVI data for Niger State and Northern Nigeria with Niger State rural harvest month prices for the period 2007-10

	NDVI state			NDVI Northern Nigeria		
Maize	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.22	0.44	0.34	0.17	0.48	-0.02
GS Avg. NDVI	-0.64	-0.58	-0.17	-0.86	-0.77	-0.52
Peak mo. NDVI value	-0.22	-0.31	-0.33	-0.99	-0.90	-0.90
NDVI val. of month w/ max anomalies	-0.60	-0.44	-0.25	-0.93	-0.97	-0.61
Local rice	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.01	0.33	-0.44	-0.33	-0.16	-0.14
GS Avg. NDVI	-0.31	-0.46	-0.99	-0.61	-0.74	-0.96
Peak mo. NDVI value	0.27	-0.01	-0.72	-0.88	-0.98	-0.67
NDVI val. of month w/ max anomalies	-0.47	-0.44	-0.98	-0.54	-0.85	-0.75
Imported rice	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.06	-0.14	-0.23	0.02	-0.36	-0.12
GS Avg. NDVI	-0.69	-0.51	-0.88	-0.90	-0.76	-0.99
Peak mo. NDVI value	-0.23	0.06	-0.47	-0.99	-0.91	-0.89
NDVI val. of month w/ max anomalies	-0.69	-0.65	-0.90	-0.89	-0.62	-0.85
Millet	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.03	0.08	-0.24	0.03	0.11	-0.26
GS Avg. NDVI	-0.74	-0.75	-0.76	-0.93	-0.93	-0.93
Peak mo. NDVI value	-0.30	-0.34	-0.27	-0.98	-0.97	-0.92
NDVI val. of month w/ max anomalies	-0.73	-0.71	-0.84	-0.91	-0.94	-0.77
Sorghum	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.32	-0.65	-0.44	-0.06	-0.62	-0.50
GS Avg. NDVI	-0.97	-0.74	-0.69	-0.99	-0.81	-0.84
Peak mo. NDVI value	-0.68	-0.29	-0.17	-0.76	-0.64	-0.81
NDVI val. of month w/ max anomalies	-0.94	-0.92	-0.85	-0.83	-0.45	-0.57
Cowpeas	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.31	-0.26	-0.35	-0.25	-0.18	-0.39
GS Avg. NDVI	-0.84	-0.86	-0.73	-0.96	-0.98	-0.89
Peak mo. NDVI value	-0.39	-0.43	-0.22	-0.88	-0.90	-0.87
NDVI val. of month w/ max anomalies	-0.90	-0.90	-0.86	-0.78	-0.82	-0.67
Cassava	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.11	-0.12	-0.16	0.37	0.32	0.33
GS Avg. NDVI	-0.86	-0.94	-0.92	-0.91	-0.86	-0.80
Peak mo. NDVI value	-0.67	-0.89	-0.94	-0.79	-0.55	-0.44
NDVI val. of month w/ max anomalies	-0.70	-0.77	-0.74	-0.98	-0.84	-0.77
Yams	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.31	0.52	-0.07	0.09	0.70	0.23
GS Avg. NDVI	-0.99	0.49	-0.93	-0.93	0.66	-0.96
Peak mo. NDVI value	-0.84	-0.05	-0.73	-0.61	-0.68	-0.76
NDVI val. of month w/ max anomalies	-0.90	0.73	-0.81	-0.80	0.34	-0.94

Note: a description of the abbreviations of the NDVI measures is included below table 2B-1.

Table 2D-7: Correlation coefficients for NDVI data for Borno State and Northern Nigeria with Borno State urban harvest month prices for the period 2001-10

	NDVI state			NDVI Northern Nigeria		
Maize	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.36	-0.48	-0.24	-0.58	-0.67	-0.44
GS Avg. NDVI	-0.45	-0.51	-0.26	-0.67	-0.65	-0.55
Peak mo. NDVI value	-0.37	-0.37	-0.19	-0.68	-0.63	-0.41
NDVI val. of month w/ max anomalies	-0.48	-0.49	-0.34	-0.47	-0.42	-0.34
Local rice	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.07	0.07	0	-0.43	-0.31	-0.36
GS Avg. NDVI	-0.10	-0.02	-0.10	-0.59	-0.44	-0.50
Peak mo. NDVI value	0.11	0.16	0.08	-0.40	-0.23	-0.32
NDVI val. of month w/ max anomalies	-0.44	-0.34	-0.40	-0.40	-0.25	-0.31
Imported rice	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0	0.09	0.10	-0.39	-0.41	-0.30
GS Avg. NDVI	-0.15	-0.03	-0.04	-0.58	-0.51	-0.53
Peak mo. NDVI value	0.04	0.19	0.17	-0.40	-0.27	-0.25
NDVI val. of month w/ max anomalies	-0.44	-0.34	-0.38	-0.34	-0.29	-0.31
Millet	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.10	-0.19	-0.05	-0.19	-0.28	-0.07
GS Avg. NDVI	-0.16	-0.27	-0.12	-0.46	-0.54	-0.35
Peak mo. NDVI value	0.04	0.19	0.17	-0.40	-0.27	-0.25
NDVI val. of month w/ max anomalies	-0.44	-0.36	-0.38	-0.34	-0.29	-0.31
Sorghum	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.20	0.10	-0.08	-0.10	-0.24	-0.35
GS Avg. NDVI	0.15	0.03	-0.23	-0.25	-0.42	-0.70
Peak mo. NDVI value	-0.01	0	-0.14	-0.23	-0.33	-0.55
NDVI val. of month w/ max anomalies	-0.04	-0.23	-0.49	-0.27	-0.42	-0.61
Cowpeas	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.16	-0.13	-0.19	-0.36	-0.47	-0.41
GS Avg. NDVI	-0.24	-0.24	-0.33	-0.60	-0.67	-0.68
Peak mo. NDVI value	-0.22	-0.05	-0.23	-0.50	-0.46	-0.58
NDVI val. of month w/ max anomalies	-0.40	-0.49	-0.50	-0.48	-0.51	-0.46
Cassava	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	0.37	0.24	0.22	-0.09	-0.16	-0.28
GS Avg. NDVI	0.23	0.12	0.08	-0.31	-0.41	-0.46
Peak mo. NDVI value	0.43	0.26	0.38	-0.02	-0.10	-0.08
NDVI val. of month w/ max anomalies	-0.23	-0.22	-0.32	-0.32	-0.29	-0.27
Yams	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.07	0.15	0.24	0.02	0.01	0.18
GS Avg. NDVI	-0.33	-0.03	0.04	-0.62	-0.46	-0.32
Peak mo. NDVI value	-0.25	-0.11	-0.13	-0.59	-0.42	-0.35
NDVI val. of month w/ max anomalies	-0.60	-0.33	-0.21	-0.52	-0.40	-0.21

Note: a description of the abbreviations of the NDVI measures is included below table 2B-1.

Table 2D-8: Correlation coefficients for NDVI data for Borno State and Northern Nigeria with Borno State rural harvest month prices for the period 2007-10

	NDVI state			NDVI Northern Nigeria		
Maize	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.72	-0.58	-0.63	-0.53	0.32	0.38
GS Avg. NDVI	-0.76	-0.75	-0.78	-0.63	-0.94	-0.91
Peak mo. NDVI value	-0.68	-0.74	-0.78	-0.80	-0.78	-0.80
NDVI val. of month w/ max anomalies	-0.23	-0.89	-0.93	-0.44	-0.96	-0.98
Local rice	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.80	-0.60	-0.79	-0.33	0.76	0.41
GS Avg. NDVI	-0.88	-0.67	-0.89	-0.83	-0.61	-0.87
Peak mo. NDVI value	-0.81	-0.73	-0.90	-0.92	-0.63	-0.89
NDVI val. of month w/ max anomalies	-0.48	-0.98	-0.96	-0.68	-0.90	-1
Imported rice	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.33	-0.54	-0.60	0.37	0.06	0.20
GS Avg. NDVI	-0.53	-0.74	-0.78	-0.86	-0.99	-0.97
Peak mo. NDVI value	-0.52	-0.69	-0.75	-0.57	-0.79	-0.81
NDVI val. of month w/ max anomalies	-0.82	-0.76	-0.85	-0.86	-0.89	-0.95
Millet	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.58	-0.69	-0.71	-0.58	0.14	0.01
GS Avg. NDVI	-0.69	-0.85	-0.86	-0.77	-0.98	-0.99
Peak mo. NDVI value	-0.59	-0.82	-0.82	-0.77	-0.89	-0.91
NDVI val. of month w/ max anomalies	-0.25	-0.84	-0.76	-0.49	-0.95	-0.91
Sorghum	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.72	-0.45	-0.79	-0.42	0.18	-0.29
GS Avg. NDVI	-0.82	-0.66	-0.88	-0.82	-0.95	-0.87
Peak mo. NDVI value	-0.74	-0.62	-0.82	-0.88	-0.71	-0.93
NDVI val. of month w/ max anomalies	-0.41	-0.79	-0.53	-0.62	-0.89	-0.72
Cowpeas	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.73	-0.72	-0.54	0.1	0.09	-0.16
GS Avg. NDVI	-0.88	-0.87	-0.73	-0.98	-0.98	-0.99
Peak mo. NDVI value	-0.84	-0.84	-0.66	-0.91	-0.91	-0.80
NDVI val. of month w/ max anomalies	-0.82	-0.82	-0.62	-0.94	-0.94	-0.80
Cassava	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.31	-0.35	0.27	0.80	0.45	0.32
GS Avg. NDVI	-0.42	0.17	0.05	-0.53	-0.32	-0.48
Peak mo. NDVI value	-0.48	0.15	0.06	-0.39	0.14	0
NDVI val. of month w/ max anomalies	-0.89	-0.38	-0.42	-0.79	-0.33	-0.42
Yams	Sept.	Oct.	Nov.	Sept.	Oct.	Nov.
Annual Avg. NDVI	-0.23	-0.35	-0.09	0.61	0.71	0.63
GS Avg. NDVI	-0.40	-0.48	-0.26	-0.67	-0.64	-0.57
Peak mo. NDVI value	-0.43	-0.53	-0.29	-0.41	-0.47	-0.27
NDVI val. of month w/ max anomalies	-0.83	-0.90	-0.75	-0.80	-0.84	-0.70

Note: a description of the abbreviations of the NDVI measures is included below table 2B-1.

Appendix 3A. On Whether to Use Nominal or Real Prices

Past price transmission studies show considerable divergence with regard to: the choice of whether or not to deflate nominal prices; and, if deflation is selected, which index to use to deflate. Mundlak and Larson (1992) estimated price transmission models using both nominal and real prices. The nominal world and domestic prices were each measured in U.S. dollars, and then deflated by the U.S. (representing world) and domestic consumer price indexes (CPIs), respectively. Baffes and Gardner (2003) used exclusively real prices in their analysis. In their framework, the world price deflator was the CPI for the associated country price designated as representative of the world price, and a domestic CPI for deflation of the relevant domestic price. With maize as an example, the U.S. corn price was used as the global market maize price, and was deflated by the U.S. CPI (Baffes and Gardner 2003). Minot (2011) used the U.S. CPI to deflate both the U.S. dollar equivalent of domestic prices (in his case domestic prices were those for countries in Sub-Saharan Africa), and the world prices, also measured in U.S. dollars.

The apparent lack of consensus with regard to both the choice to deflate nominal prices, and, if deflation was chosen, determination of the relevant index upon which to deflate, motivates a closer look at the literature for guidance. The deflation decision is important because deflating a price series can change the time series properties of variable series, either introducing a trend or creating a de-trended series (with impacts on series stationarity) (Peterson and Tomek 2000). Peterson and Tomek (2000) argued the choices of whether to deflate nominal prices and the conditional selection of a relevant deflator are most likely to be viable if guided by economic theory and logic. If theory and logic do not provide a clear choice, then empirical investigation may be needed to justify analyst choices of data transformations (Peterson and Tomek 2000). This advice was followed in our analysis, with reference to the law of one price (LOP) theory. In LOP theory, as described, for example, by Fafchamps and Hill (2008), arbitrage occurs because traders implement market activities base on nominal price signals. Thus, within a price transmission model, inclusion of exclusively nominal prices is viewed as the theoretically and logically consistent approach. The prices included in all econometric models were, therefore, not deflated.

Appendix 3B. World, Neighbor Country, Urban, and Rural Price Series Summary Statistics and Plots of World, Neighbor Country, and Urban Price Series

Table 3B-1: World maize price summary statistics for the period January 2001 to December 2010

Price series	***n***	**Mean**	**SD**	**CV**	**ADF**	**PP**	**ADF Δ**	**PP Δ**
World Bank (US Gulf)	*120*	17.87	6.69	0.37	0.12	-0.13	-5.26***	-8.84***
IMF (US Gulf)	*120*	17.85	6.69	0.37	0.12	-0.13	-5.24***	-8.73***
GIEWS International (US Gulf)	*120*	17.83	6.65	0.37	0.15	-0.09	-5.10***	-8.64***
FAO (US Gulf)	*120*	17.81	6.63	0.37	0.18	-0.17	-4.69***	-8.61***
GIEWS International (Argentina)	*120*	17.49	6.97	0.40	0.92	0.45	-4.83***	-8.83***
FAO (Argentina)	*120*	17.47	6.94	0.40	0.86	0.38	-2.76***	-9.17***
SAFEX (South Africa)	*108*	22.97	5.75	0.25	-2.27	-2.47	-9.00***	-8.94***

Note: units for mean and standard deviation (SD) are Naira/kilogram. CV is the coefficient of variation, which is the SD divided by the mean. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Critical values for ADF and PP statistics for n=100 are -3.50, -2.90, and -2.59; for n=50 are -3.59, -2.93, and -2.60. Δ is the first difference ($p_t - p_{t-1}$). ADF and PP statistics for the first difference of each series have the critical values for n=100 are -2.60, -1.95, and -1.61. All critical values are provided in Fuller (1996).

Table 3B-2: World sorghum and cassava price summary statistics for the period January 2001 to December 2010

Price series	***n***	**Mean**	**SD**	**CV**	**ADF**	**PP**	**ADF Δ**	**PP Δ**
				Sorghum				
World Bank (US Gulf)	*120*	17.21	5.67	0.33	-0.33	-0.68	-5.99***	-9.17***
FAO (US Gulf)	*120*	18.16	6.40	0.35	0.14	-0.03	-4.88***	-9.06***
GIEWS International (US Gulf)	*120*	18.11	6.33	0.35	0.16	0.00	-4.97***	-9.07***
				Cassava				
GIEWS (Bangkok, Thailand)	*120*	32.67	16.7	0.51	0.38	0.79	-2.49**	-6.73***

Note: a description of table contents is included below table 3B-1.

Table 3B-3: World rice price summary statistics for the period January 2001 to December 2010

Price series	*n*	Mean	SD	CV	ADF	PP	ADF Δ	PP Δ
World Bank (Thai A1)	*120*	33.42	16.17	0.48	-1.67	-1.46	-6.89***	-6.30***
FAO (Thai A1 super)	*120*	33.84	16.64	0.49	-0.56	-1.39	-3.93***	-5.73***
World Bank (Thai 25% broken)	*115*	38.81	18.55	0.48	-1.76	-1.92	-7.49***	-7.40***
World Bank (Thai 5% broken)	*120*	45.04	23.42	0.52	-0.57	-1.08	-6.31***	-7.05***
IMF (Thai 5% broken)	*120*	46.82	25.87	0.55	-0.69	-1.26	-6.20***	-6.67***
GIEWS International (Thai, 100% parboiled)	*120*	47.82	26.98	0.56	-0.92	-1.19	-3.57***	-6.03***
FAO (Thai 100%B 2nd grade)	*120*	46.97	25.34	0.54	-0.55	-1.04	-3.29***	-6.13***
World Bank (Vietnamese 5% broken)	*74*	46.32	16.82	0.36	-1.13	-2.25	-5.10***	-4.09***
GIEWS International (Vietnamese 25% broken)	*120*	36.76	18.21	0.50	-0.56	-1.70	-4.46***	-5.83***
GIEWS International (Vietnamese 5% broken)	*120*	40.10	20.07	0.50	-0.99	-1.62	-6.14***	-5.94***
GIEWS International (US)	*120*	53.83	22.79	0.42	-1.31	-1.08	-6.56***	-6.57***
GIEWS International (Uruguay)	*60*	69.90	19.56	0.28	-1.71	-1.81	-7.62***	-7.64***
GIEWS International (India 25% broken)	*62*	25.63	7.81	0.30	-0.04	-0.15	-5.82***	-5.74***

Note: a description of table contents is included below table 3B-1.

Table 3B-4: Neighboring country maize price summary statistics for the period January 2001 to December 2010

Price series	***n***	**Mean**	**SD**	**CV**	**ADF**	**PP**	**ADF Δ**	**PP Δ**
Randfontein, South Africa	*120*	21.84	6.35	0.29	-2.09	-2.21	-10.06***	-10.06***
Cotonou, Benin	*120*	46.26	20.44	0.44	-1.97	-2.28	-3.09***	-9.53***
Malanville, Benin	*100*	30.72	14.20	0.46	0.07	-3.14**	-5.31***	-9.35***
Lomé, Togo	*120*	43.48	21.79	0.50	-1.85	-1.73	-11.51***	-11.58***
Korbongou, Togo	*120*	30.41	14.03	0.46	-1.73	-2.57	-6.18***	-10.03***
Accra, Ghana	*60*	49.86	13.84	0.28	-1.43	-2.16	-4.52***	-6.14***
Bolgatanga, Ghana	*60*	39.68	12.23	0.31	-1.83	-1.95	-6.59***	-6.54***
Niamey, Niger	*120*	44.39	16.01	0.36	-1.67	-1.85	-7.89***	-7.35***
Maradi, Niger	*120*	42.74	16.08	0.38	-1.71	-1.85	-7.85***	-7.68***
N'Djamena, Chad	*87*	53.24	15.66	0.29	-2.73*	-2.26	-7.15***	-7.01***
Yaoundé, Cameroon	*72*	65.14	19.95	0.31	-0.90	-0.81	-8.88***	-8.90***
Garoua, Cameroon	*72*	50.77	12.93	0.25	-2.38	-2.36	-8.00***	-8.74***
Bamako, Mali	*48*	48.96	10.28	0.21	-1.79	-1.86	-5.38***	-5.35***
Mopti, Mali	*95*	37.06	11.53	0.31	-1.97	-2.31	-7.86***	-7.84***

Note: a description of table contents is included below table 3B-1.

Table 3B-5: Neighboring country rice price summary statistics for the period January 2001 to December 2010

Price series	***n***	**Mean**	**SD**	**CV**	**ADF**	**PP**	**ADF Δ**	**PP Δ**
Cotonou, Benin	*120*	96.33	35.91	0.37	0.07	-0.06	-9.90***	-10.98***
Lomé, Togo	*120*	86.78	47.20	0.54	-0.06	-1.53	-4.90***	-18.43***
Korbongou, Togo	*117*	80.84	29.91	0.37	0.01	-1.41	-8.00***	-14.40***
Accra, Ghana	*50*	130.83	20.59	0.16	-1.77	-1.73	-6.83***	-6.83***
Bolgatanga, Ghana	*49*	109.86	15.20	0.14	-1.33	-2.11	-11.44***	-12.03***
Ouagadougou, Burkina Faso	*60*	86.14	23.97	0.28	-1.28	-1.26	-8.09***	-8.08***
Dori, Burkina Faso	*60*	94.50	24.45	0.26	-1.34	-1.13	-5.44***	-5.40***
Niamey, Niger	*120*	84.18	29.65	0.35	-0.49	-0.37	-10.15***	-10.10***
Maradi, Niger	*120*	90.44	37.41	0.41	-0.56	-0.17	-3.68***	-9.44***
N'Djamena, Chad	*87*	117.58	24.30	0.21	-1.37	-3.46**	-2.82***	-14.27***
Yaoundé, Cameroon	*72*	105.32	26.78	0.25	-1.06	-1.10	-7.03***	-7.00***
Garoua, Cameroon	*72*	111.19	24.13	0.22	-1.13	-1.10	-8.88***	-8.88***
Bamako, Mali	*60*	85.45	17.06	0.20	-2.01	-1.80	-9.05***	-9.39***
Mopti, Mali	*48*	90.28	15.21	0.17	-1.76	-2.01	-5.17***	-5.11***

Note: a description of table contents is included below table 3B-1.

Table 3B-6: Neighboring country sorghum price summary statistics for the period January 2001 to December 2010

Price series	***n***	**Mean**	**SD**	**CV**	**ADF**	**PP**	**ADF Δ**	**PP Δ**
Malanville, Benin	*100*	36.12	15.45	0.43	-1.62	-3.78***	-3.99***	-8.00***
Lomé, Togo	*120*	62.39	24.59	0.39	-1.67	-2.91**	-7.16***	-14.70***
Korbongou, Togo	*120*	31.62	19.20	0.61	-3.15**	-6.77***	-12.60***	-23.68***
Accra, Ghana	*60*	64.37	14.45	0.22	-0.64	-0.87	-6.60***	-6.71***
Bolgatanga, Ghana	*60*	41.86	11.85	0.28	-1.60	-1.44	-9.43***	-9.48***
Ouagadougou, Burkina Faso	*60*	36.45	8.35	0.23	-1.45	-1.83	-5.54***	-8.83***
Dori, Burkina Faso	*60*	40.33	9.36	0.23	-1.16	-1.40	-5.29***	-6.76***
Niamey, Niger	*120*	47.78	15.09	0.32	-2.27	-2.01	-7.70***	-7.54***
Maradi, Niger	*116*	35.03	12.48	0.36	-1.70	-2.43	-2.09**	-7.40***
N'Djamena, Chad	*87*	43.48	15.77	0.36	-2.42	-2.11	-7.28***	-7.17***
Moundou, Chad	*87*	36.96	15.17	0.41	-1.92	-2.31	-2.46**	-9.09***
Bamako, Mali	*60*	36.84	8.97	0.24	-0.99	-2.17	-3.77***	-6.52***
Mopti, Mali	*95*	38.85	10.05	0.26	-2.42	-1.96	-6.53***	-6.50***

Note: a description of table contents is included below table 3B-1.

Table 3B-7: Neighboring country millet price summary statistics for the period January 2001 to December 2010

Price series	***n***	**Mean**	**SD**	**CV**	**ADF**	**PP**	**ADF Δ**	**PP Δ**
Accra, Ghana	*60*	80.08	15.15	0.19	-1.53	-1.24	-10.27***	-10.41***
Bolgatanga, Ghana	*60*	54.17	13.33	0.25	-1.86	-1.70	-8.82***	-9.02***
Ouagadougou, Burkina Faso	*60*	40.55	9.96	0.25	-1.91	-1.78	-9.68***	-9.69***
Dori, Burkina Faso	*60*	44.70	10.83	0.24	-1.38	-1.51	-5.85***	-5.80***
Niamey, Niger	*120*	47.37	15.72	0.33	-2.35	-1.95	-7.28***	-7.98***
Maradi, Niger	*120*	35.57	12.11	0.34	-1.88	-2.50	-2.51**	-8.43***
N’Djamena, Chad	*87*	54.54	17.11	0.31	-2.17	-2.25	-8.51***	-8.50***
Moundou, Chad	*87*	46.60	17.50	0.38	-1.89	-2.09	-7.66***	-7.67***
Bamako, Mali	*72*	40.42	10.04	0.25	-2.52	-2.59*	-9.64***	-9.61***
Mopti, Mali	*95*	41.02	10.61	0.26	-2.20	-1.84	-3.63***	-6.25***

Note: a description of table contents is included below table 3B-1.

Table 3B-8: Neighboring country cassava, yams, and cowpeas price summary statistics for the period January 2001 to December 2010

Price series	***n***	**Mean**	**SD**	**CV**	**ADF**	**PP**	**ADF Δ**	**PP Δ**
				Cassava				
Cotonou, Benin	*120*	60.36	26.56	0.44	-1.54	-1.63	-9.52***	-9.50***
Malanville, Benin	*102*	45.96	18.36	0.40	-1.59	-1.51	-4.48***	-12.28***
Lomé, Togo	*120*	51.19	26.92	0.53	0.30	-0.63	-4.07***	-13.29***
Korbongou, Togo	*120*	48.60	16.75	0.34	-1.08	-2.50	-6.56***	-13.00***
Accra, Ghana	*59*	23.75	5.24	0.22	-2.11	-2.19	-7.19***	-7.18***
Yaoundé, Cameroon	*72*	27.29	5.65	0.21	-1.10	-1.43	-4.27***	-7.60***
				Yams				
Accra, Ghana	*60*	49.66	17.29	0.35	0.67	-2.79*	-6.11***	-4.81***
Bolgatanga, Ghana	*57*	49.25	16.87	0.34	-2.90*	2.82*	-7.58***	-7.67***
				Cowpeas				
Garoua, Cameroon	*72*	157.52	35.19	0.22	-1.70	-1.45	-10.02***	-10.19***
Cotonou, Benin	*48*	132.14	43.62	0.33	-1.52	-1.26	-6.35***	-7.43***
Niamey, Niger	*104*	71.38	27.39	0.38	-0.90	-2.64*	-4.90***	-8.40***
Maradi, Niger	*86*	57.40	26.75	0.47	-1.17	-2.24	-6.38***	-6.30***

Note: a description of table contents is included below table 3B-1.

Table 3B-9: Nigerian urban maize, millet, and sorghum price summary statistics for the period January 2001 to December 2010

Price series	***n***	**Mean**	**SD**	**CV**	**ADF**	**PP**	**ADF Δ**	**PP Δ**
				Maize				
Lagos State	*120*	62.64	22.17	0.35	-0.83	-1.79	-6.77***	-16.75***
Rivers State	*120*	72.41	23.14	0.32	-1.37	-2.51	-12.71***	-22.83***
Enugu State	*120*	66.66	24.66	0.37	-0.83	-1.66	-8.27***	-15.69***
Federal Capital Territory (Abuja)	*120*	51.47	18.97	0.37	-1.07	-1.48	-3.15***	-13.83***
Kano State	*108*	39.53	12.22	0.31	-2.05	-2.89*	-5.31***	-12.86***
Borno State	*108*	44.78	14.21	0.32	-3.04**	-2.78*	-13.05***	-13.83***
				Millet				
Lagos State	*108*	66.74	22.59	0.34	-2.48	-2.77*	-4.29***	-19.73***
Rivers State	*108*	68.95	25.12	0.36	-1.13	-1.13	-12.77***	-13.04***
Enugu State	*108*	70.95	29.31	0.41	-1.11	-1.35	-13.92***	-14.38***
Federal Capital Territory (Abuja)	*108*	53.57	19.76	0.37	-0.85	-1.68	-4.73***	-12.61***
Kano State	*108*	39.13	13.26	0.34	-2.29	-2.71*	-5.13***	-11.42***
Borno State	*96*	43.19	17.27	0.40	-1.85	-2.09	-4.83***	-10.39***
				Sorghum				
Lagos State	*120*	73.35	25.05	0.34	-1.26	-1.99	-12.01***	-19.15***
Rivers State	*120*	75.56	29.38	0.39	-0.33	-1.57	-5.22***	-15.13***
Enugu State	*120*	66.28	25.71	0.39	-1.39	-1.60	-19.11***	-20.79***
Federal Capital Territory (Abuja)	*120*	53.42	20.83	0.39	-1.22	-1.42	-13.31***	-13.25***
Kano State	*108*	38.52	13.15	0.34	-2.76*	-2.81*	-6.18***	-13.40***
Borno State	*108*	43.48	11.50	0.26	-2.12	-2.01	-12.18***	-12.20***

Note: a description of table contents is included below table 3B-1.

Table 3B-10: Nigerian urban cassava, yams, and cowpeas price summary statistics for the period January 2001 to December 2010

Price series	*n*	Mean	SD	CV	ADF	PP	ADF Δ	PP Δ
				Cassava				
Lagos State	*120*	69.16	20.67	0.30	-0.22	-2.19	-4.26***	-15.83***
Rivers State	*120*	79.19	20.07	0.25	-1.05	-4.04***	-7.32***	-22.14***
Enugu State	*120*	72.52	19.71	0.27	-1.75	-2.52	-10.81***	-15.64***
Federal Capital Territory (Abuja)	*120*	67.52	21.28	0.32	-0.20	-1.31	-5.68***	-14.67***
Kano State	*120*	64.93	22.10	0.34	-0.61	-1.23	-2.51**	-14.97***
Borno State	*108*	82.30	16.21	0.20	-2.88*	-2.55	-12.54***	-13.51***
				Yams				
Lagos State	*120*	69.24	28.71	0.41	-0.41	-3.00**	-8.41***	-19.71***
Rivers State	*120*	69.45	19.38	0.28	-3.81***	-4.43***	-15.11***	-16.53***
Enugu State	*120*	73.99	29.08	0.39	-0.71	-1.57	-10.08***	-12.72***
Federal Capital Territory (Abuja)	*120*	60.99	23.24	0.38	0.82	-2.37	-7.75***	-16.04***
Kano State	*108*	65.16	26.39	0.41	-0.11	-3.39**	-3.46***	-16.24***
Borno State	*108*	66.43	20.83	0.31	-2.49	-3.38**	-15.14***	-17.72***
				Cowpeas				
Lagos State	*120*	110.24	37.69	0.34	-1.56	-1.44	-12.47***	-12.49***
Rivers State	*120*	113.70	40.48	0.36	-0.93	-1.67	-9.14***	-20.49***
Enugu State	*120*	117.42	44.05	0.38	-1.66	-1.75	-14.80***	-15.72***
Federal Capital Territory (Abuja)	*108*	110.04	37.24	0.34	-1.47	-1.58	-12.30***	-12.17***
Kano State	*120*	97.09	40.34	0.42	-1.23	-1.97	-2.68***	-12.29***
Borno State	*108*	88.04	34.46	0.39	-2.88*	-2.55	-13.94***	-14.22***

Note: a description of table contents is included below table 3B-1.

Table 3B-11: Nigerian urban local Rice and imported rice price summary statistics for the period January 2001 to December 2010

Price series	***n***	**Mean**	**SD**	**CV**	**ADF**	**PP**	**ADF Δ**	**PP Δ**
				Local Rice				
Lagos State	*120*	99.61	37.26	0.37	-1.36	-1.51	-18.74***	-18.99***
Rivers State	*120*	100.82	32.75	0.32	-1.86	-3.43**	-7.85***	-19.58***
Enugu State	*120*	90.80	31.28	0.34	-0.97	-1.50	-6.86***	-15.52***
Federal Capital Territory (Abuja)	*120*	96.89	31.32	0.32	-0.68	-2.02	-6.51***	-19.66***
Kano State	*108*	77.91	24.85	0.32	-1.63	-1.50	-5.16***	-11.15***
Borno State	*108*	93.81	26.74	0.29	-1.22	-2.00	-9.85***	-15.36***
				Imported Rice				
Lagos State	*120*	114.75	37.65	0.33	-1.06	-1.54	-8.59***	-19.23***
Rivers State	*120*	132.34	45.41	0.34	-0.80	-0.84	-16.01***	-17.88***
Enugu State	*120*	122.26	45.40	0.37	-1.00	-1.48	-16.88***	-18.22***
Federal Capital Territory (Abuja)	*120*	123.68	41.16	0.33	-0.65	-1.12	-5.10***	-16.58***
Kano State	*108*	113.51	40.35	0.36	-1.68	-1.57	-7.75***	-17.02***
Borno State	*108*	131.07	37.40	0.29	-0.66	-0.96	-5.01***	-17.17***

Note: a description of table contents is included below table 3B-1.

Table 3B-12: Nigerian rural and urban maize price summary statistics for the period January 2007 to December 2010

Price series		*n*	Mean	SD	CV	ADF	PP	ADF Δ	PP Δ
Lagos State	*urban*	*48*	84.35	16.96	0.20	-2.15	-2.10	-8.65***	-8.58***
	rural	*48*	88.07	20.71	0.24	-1.89	-1.82	-8.17***	-8.25***
Rivers State	*urban*	*48*	93.56	16.86	0.18	-2.37	-3.03**	-10.40***	-11.76***
	rural	*48*	91.42	21.42	0.23	-1.90	-1.97	-0.90	-8.02***
Enugu State	*urban*	*48*	89.68	15.50	0.17	-1.44	-2.43	-5.54***	-12.93***
	rural	*48*	88.25	15.90	0.18	-1.65	-2.41	-10.54***	-10.73***
Federal Capital Territory (Abuja)	*urban*	*48*	67.15	18.30	0.27	-1.60	-1.50	-1.88*	-5.46***
	rural	*48*	53.93	13.26	0.25	-3.69***	-2.11	-9.20***	-9.12***
Kano State	*urban*	*36*	47.94	10.37	0.22	-1.87	-1.85	-7.05***	-7.06***
	rural	*48*	49.74	10.60	0.21	-2.21	-2.11	-7.48***	-7.61***
Borno State	*urban*	*48*	52.98	14.16	0.27	-1.53	-2.19	-6.05***	-9.21***
	rural	*48*	52.63	11.61	0.22	-2.41	-3.27**	-9.74***	-10.20***

Note: a description of table contents is included below table 3B-1.

Table 3B-13: Nigerian rural and urban millet price summary statistics for the period January 2007 to December 2010

Price series		***n***	**Mean**	**SD**	**CV**	**ADF**	**PP**	**ADF Δ**	**PP Δ**
Lagos State	*urban*	*36*	90.08	15.65	0.17	-0.47	-2.07	-3.60***	-8.89***
	rural	*48*	78.18	14.53	0.19	-1.58	-4.01***	-6.56***	-13.37***
Rivers State	*urban*	*36*	93.87	19.01	0.20	-2.09	-2.05	-6.48***	-6.55***
	rural	*48*	73.27	12.28	0.17	-3.05**	-3.08**	-7.10***	-7.34***
Enugu State	*urban*	*36*	106.30	12.33	0.12	-2.97**	-2.90**	-8.50***	-8.85***
	rural	*48*	81.36	10.74	0.13	1.80	-2.98***	-10.69***	-11.62***
Federal Capital Territory (Abuja)	*urban*	*36*	73.85	17.15	0.23	-2.54	-1.37	-7.34***	-6.04***
	rural	*48*	61.46	13.75	0.22	-1.81	-2.14	-10.44***	-10.59***
Kano State	*urban*	*36*	47.86	9.54	0.20	-1.02	-1.00	-5.69***	-5.73***
	rural	*48*	47.29	9.50	0.20	-2.24	-2.41	-5.59***	-5.61***
Borno State	*urban*	*36*	56.05	17.46	0.31	-0.46	-0.53	-1.60*	-6.26***
	rural	*48*	44.45	9.45	0.21	-2.56	-2.45	-10.57***	-10.89***

Note: a description of table contents is included below table 3B-1.

Table 3B-14: Nigerian rural and urban sorghum price summary statistics for the period January 2007 to December 2010

Price series		***n***	**Mean**	**SD**	**CV**	**ADF**	**PP**	**ADF Δ**	**PP Δ**
Lagos State	*urban*	*48*	96.42	18.38	0.19	-0.95	-1.60	-12.51***	-12.36***
	rural	*48*	90.55	21.58	0.24	-1.28	-1.91	-10.28***	-10.66***
Rivers State	*urban*	*48*	103.98	18.41	0.18	-2.95**	-2.83*	-7.67***	-8.95***
	rural	*48*	90.91	23.96	0.26	-1.85	-1.53	-8.99***	-9.60***
Enugu State	*urban*	*48*	91.14	16.43	0.18	-1.35	-1.72	-10.99***	-11.66***
	rural	*48*	89.79	14.43	0.16	-1.40	-4.96***	-6.95***	-19.87***
Federal Capital Territory (Abuja)	*urban*	*48*	71.25	18.86	0.26	-1.66	-1.65	-5.74***	-5.67***
	rural	*48*	59.38	14.79	0.25	-2.20	-2.07	-8.66***	-8.86***
Kano State	*urban*	*36*	46.85	10.01	0.21	-1.82	-1.74	-6.59***	-6.78***
	rural	*48*	46.19	9.92	0.21	-2.36	-2.34	-7.16***	-7.18***
Borno State	*urban*	*48*	49.84	9.59	0.19	-2.32	-1.41	-10.36***	-10.69***
	rural	*48*	48.66	10.63	0.22	-2.24	-2.61*	-6.03***	-12.36***

Note: a description of table contents is included below table 3B-1.

Table 3B-15: Nigerian rural and urban cassava price summary statistics for the period January 2007 to December 2010

Price series		***n***	**Mean**	**SD**	**CV**	**ADF**	**PP**	**ADF Δ**	**PP Δ**
Lagos State	*urban*	*48*	84.81	17.54	0.21	-2.50	-2.53	-8.73***	-8.88***
	rural	*48*	81.01	19.86	0.25	0.04	-0.56	-1.65*	-8.73***
Rivers State	*urban*	*48*	93.52	14.84	0.16	-4.39***	-4.52***	-8.98***	-10.36***
	rural	*48*	88.43	17.36	0.20	-1.20	-1.63	-10.34***	-11.10***
Enugu State	*urban*	*48*	84.67	23.82	0.28	-1.03	-1.98	-9.94***	-10.33***
	rural	*48*	80.97	13.10	0.16	-2.24	-3.86***	-12.03***	-14.16***
Federal Capital Territory (Abuja)	*urban*	*48*	85.41	17.32	0.20	-0.96	-1.37	-11.26***	-12.64***
	rural	*48*	80.07	24.49	0.31	-1.23	-1.38	-9.36***	-9.58***
Kano State	*urban*	*48*	80.95	23.05	0.28	-0.93	-1.06	-10.08***	-10.43***
	rural	*48*	76.20	21.03	0.28	-0.04	-1.26	-8.96***	-9.22***
Borno State	*urban*	*48*	91.43	15.76	0.17	-2.43	-2.14	-9.59***	-10.46***
	rural	*48*	86.56	13.05	0.15	-0.59	-2.52	-5.84***	-10.21***

Note: a description of table contents is included below table 3B-1.

Table 3B-16: Nigerian rural and urban yams price summary statistics for the period January 2007 to December 2010

Price series		***n***	**Mean**	**SD**	**CV**	**ADF**	**PP**	**ADF Δ**	**PP Δ**
Lagos State	*urban*	*48*	96.41	20.65	0.21	-1.49	-4.26***	-5.32***	-12.72***
	rural	*48*	98.68	25.20	0.26	-3.01**	-2.88*	-7.78***	-8.30***
Rivers State	*urban*	*48*	82.73	17.57	0.21	-1.54	-3.29**	-6.00***	-10.79***
	rural	*48*	87.00	9.31	0.11	-4.95***	-4.73***	-4.86***	-8.86***
Enugu State	*urban*	*48*	98.92	24.04	0.24	-1.29	-1.72	-6.77***	-5.45***
	rural	*48*	96.14	22.30	0.23	-0.96	-0.55	-2.39***	-7.84***
Federal Capital Territory (Abuja)	*urban*	*48*	79.24	23.37	0.29	-0.91	-1.48	-4.84***	-7.10***
	rural	*48*	65.58	19.30	0.29	-1.34	-3.33**	-5.80***	-7.84***
Kano State	*urban*	*36*	92.24	20.70	0.22	-6.34***	-4.26***	-8.14***	-5.08***
	rural	*48*	91.38	22.06	0.24	2.18	-3.44***	-8.68***	-16.13***
Borno State	*urban*	*48*	77.56	20.99	0.27	-1.53	-1.91	-9.96***	-11.28***
	rural	*48*	74.83	23.16	0.31	0.84	-3.95***	-3.36***	-7.54***

Note: a description of table contents is included below table 3B-1.

Table 3B-17: Nigerian rural and urban cowpeas price summary statistics for the period January 2007 to December 2010

Price series		***n***	**Mean**	**SD**	**CV**	**ADF**	**PP**	**ADF Δ**	**PP Δ**
Lagos State	*urban*	*48*	146.10	29.80	0.20	-1.44	-1.99	-4.62***	-7.21***
	rural	*36*	141.72	41.57	0.29	-1.87	-1.66	-7.27***	-7.23***
Rivers State	*urban*	*48*	153.32	25.74	0.17	-1.19	-1.96	-8.72***	-11.55***
	rural	*39*	142.21	31.86	0.22	-3.48***	-1.83	-9.23***	-10.07***
Enugu State	*urban*	*48*	160.27	33.82	0.21	-1.56	-1.57	-6.63***	-6.63***
	rural	*36*	137.76	28.25	0.21	-1.27	-1.76	-6.83***	-9.42***
Federal Capital Territory (Abuja)	*urban*	*48*	138.02	35.20	0.26	-1.33	-1.33	-6.94***	-6.94***
	rural	*36*	119.65	28.31	0.24	-0.46	-0.90	-0.15	-6.52***
Kano State	*urban*	*48*	131.50	38.92	0.30	-1.85	-2.12	-4.51***	-7.80***
	rural	*48*	97.20	23.71	0.24	-2.84*	-2.74*	-8.42***	-8.81***
Borno State	*urban*	*48*	114.97	32.60	0.28	-1.83	-1.89	-9.97***	-10.62***
	rural	*48*	113.17	32.00	0.28	-3.74***	-1.81	-1.59	-11.18***

Note: a description of table contents is included below table 3B-1.

Table 3B-18: Nigerian rural and urban local rice price summary statistics for the period January 2007 to December 2010

Price series		***n***	**Mean**	**SD**	**CV**	**ADF**	**PP**	**ADF Δ**	**PP Δ**
Lagos State	*urban*	*48*	132.98	23.61	0.18	-1.76	-1.57	-9.44***	-9.60***
	rural	*48*	128.68	11.02	0.09	-3.35**	-3.42**	-9.20***	-9.19***
Rivers State	*urban*	*48*	125.35	26.39	0.21	-1.32	-3.46***	-5.38***	-9.59***
	rural	*48*	119.23	23.87	0.20	-3.15***	-3.10***	-10.28***	-10.36***
Enugu State	*urban*	*48*	120.57	21.19	0.18	-2.13	-1.91	-9.52***	-9.66***
	rural	*48*	111.13	15.90	0.14	-1.73	-2.95**	-9.71***	-11.31***
Federal Capital Territory (Abuja)	*urban*	*48*	128.21	16.59	0.13	-3.50**	-3.46**	-10.70***	-11.14***
	rural	*48*	119.33	14.79	0.12	-0.84	-1.27	-8.98***	-8.70***
Kano State	*urban*	*36*	103.92	17.26	0.17	-1.42	-1.43	-5.08***	-5.06***
	rural	*48*	104.35	13.34	0.13	-2.73*	-2.66*	-7.90***	-8.12***
Borno State	*urban*	*48*	116.36	18.81	0.16	-1.33	-2.53	-6.61***	-8.65***
	rural	*48*	109.45	19.60	0.18	-1.23	-2.26	-6.48***	-10.31***

Note: a description of table contents is included below table 3B-1.

Table 3B-19: Nigerian rural and urban imported rice price summary statistics for the period January 2007 to December 2010

Price series		***n***	**Mean**	**SD**	**CV**	**ADF**	**PP**	**ADF Δ**	**PP Δ**
Lagos State	*urban*	*48*	151.39	21.32	0.14	-1.91	-1.77	-8.01***	-8.11***
	rural	*48*	153.83	20.98	0.14	-2.50	-2.09	-9.28***	-9.49***
Rivers State	*urban*	*48*	172.59	33.62	0.19	-0.83	-1.16	-10.82***	-10.64***
	rural	*48*	168.13	31.34	0.19	-0.07	-1.57	-13.18***	-15.20***
Enugu State	*urban*	*48*	165.77	30.92	0.19	-1.85	-2.01	-10.45***	-10.68***
	rural	*48*	166.03	26.81	0.16	-1.01	-2.08	-6.18***	-9.66***
Federal Capital Territory (Abuja)	*urban*	*48*	164.50	22.16	0.13	-1.61	-1.92	-7.50***	-7.52***
	rural	*48*	156.37	21.26	0.14	-1.45	-1.42	-8.58***	-8.37***
Kano State	*urban*	*36*	155.88	27.52	0.18	-1.18	-0.86	-7.56***	-8.50***
	rural	*48*	155.91	20.70	0.13	-1.67	-1.84	-12.03***	-11.87***
Borno State	*urban*	*48*	163.70	26.11	0.16	-1.46	-1.90	-10.62***	-10.86***
	rural	*48*	163.43	26.08	0.16	-1.52	-1.79	-11.99***	-13.62***

Note: a description of table contents is included below table 3B-1.

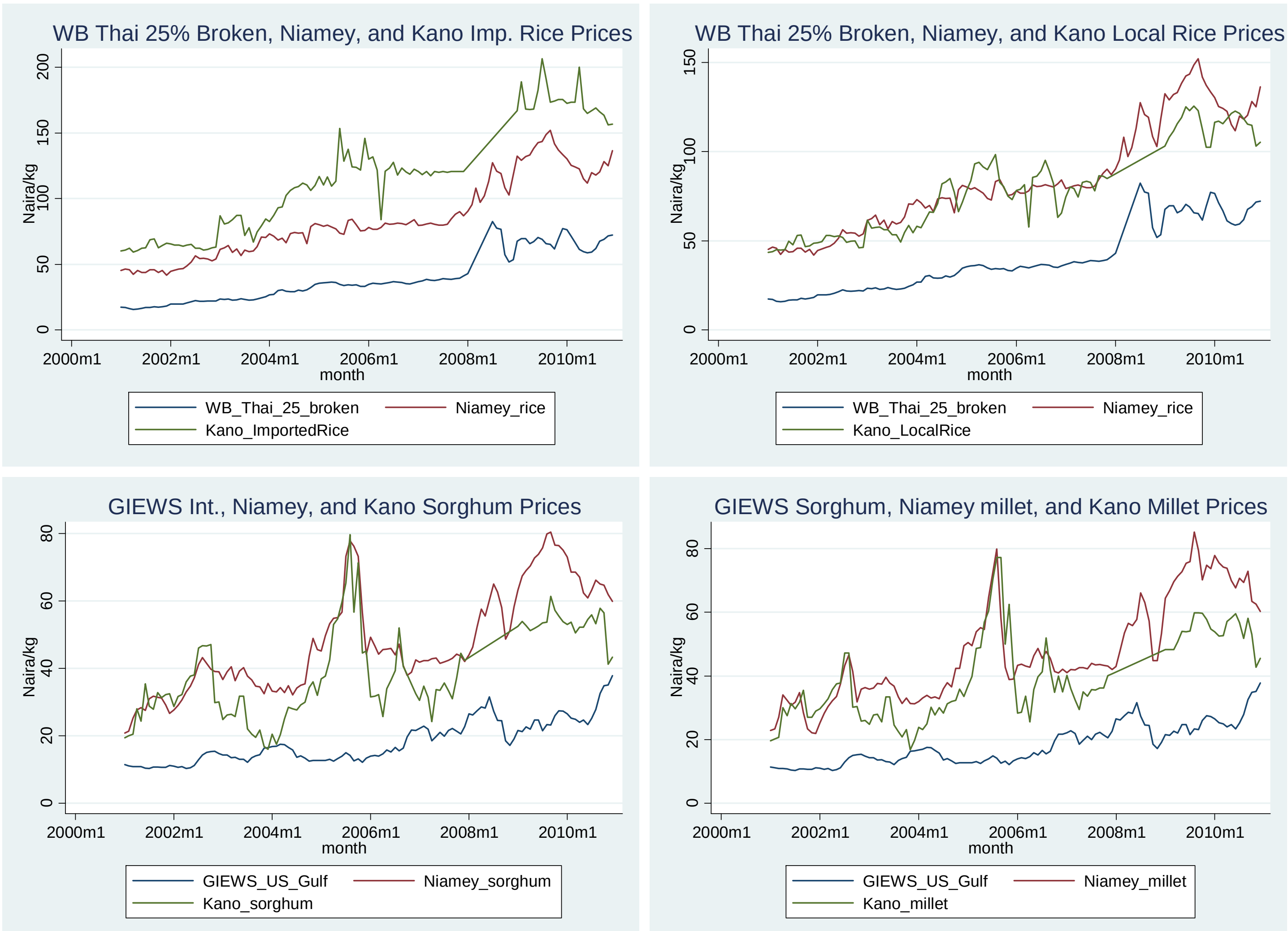

Figure 3B-1: Plots of imported rice, local rice, sorghum, and millet world, neighbor country, and urban price series

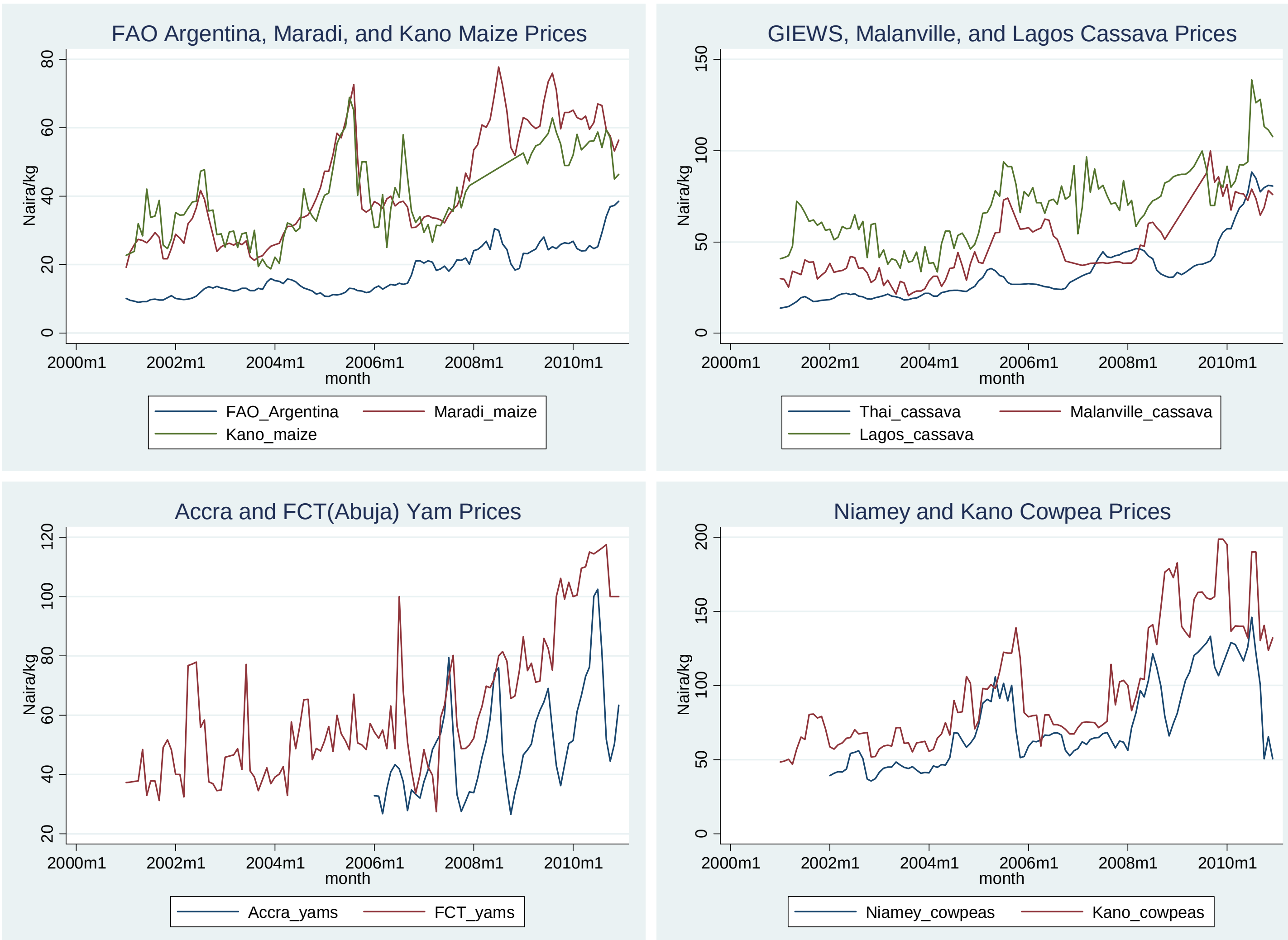

Figure 3B-2: Plots of maize, cassava, yams, and cowpeas world, neighbor country, and urban price series

Appendix 3C. Unitary Cointegration Results for Price Series in Levels Models Reported in Figures 3-2 through 3-7

Table 3C-1: Unitary cointegration results for levels models for maize, imported rice, and local rice

Set	Cointegration statistic	Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Maize							
World : FAO Argentina	ADF	-1.94	-1.50	-1.53	-2.09	-3.31**	-3.60***
	PP	-2.69*	-3.87***	-2.51	-2.44	-3.36**	-3.50***
Neighbor country: Maradi, Niger	ADF	-3.15**	-1.29	-1.73	-2.70*	-2.23	-4.76***
	PP	-4.04***	-5.83***	-3.27**	-4.53***	-5.06***	-5.09***
Nigeria Commercial Hub (urban): Kano State	ADF	-2.05	-0.67	-0.88	-2.35	…	-3.67***
	PP	-3.21**	-4.62***	-2.54	-3.69***	…	-6.19***
Urban-to-rural	ADF	-3.19**	-4.44***	-5.49***	-2.10	-4.13***	-4.07***
	PP	-2.67*	-4.40***	-5.56***	-2.12	-4.04***	-4.06***
Imported Rice							
World: WB Thai 25% broken	ADF	-1.66	0.18	-1.96	-0.87	-1.81	-1.74
	PP	-3.10**	-2.35	-2.42	-2.03	-2.19	-2.38
Neighbor country: Niamey, Niger	ADF	-2.63*	-2.76*	-1.59	-1.63	-3.14**	-2.92**
	PP	-5.85***	-3.93***	-4.50***	-3.78***	-3.66***	-5.11***
Nigeria Commercial Hub (urban): Kano State	ADF	-1.43	-2.46	-2.14	-7.24***	…	-6.53***
	PP	-7.54***	-3.63***	-6.07***	-7.42***	…	-6.72***
Urban-to-rural	ADF	-6.57***	-4.36***	-4.10***	-3.51**	-1.46	-6.05***
	PP	-6.57***	-4.34***	-4.16***	-3.53**	-4.71***	-6.12***
Local Rice							
World: WB Thai 25% broken	ADF	-2.14	-4.08***	-1.60	-1.16	-1.60	-1.59
	PP	-2.88*	-6.57***	-3.18**	-4.31***	-3.47**	-5.08***
Neighbor country: Niamey, Niger	ADF	-3.47**	-6.81***	-5.59***	-6.04***	-2.42	-5.31***
	PP	-5.46***	-6.85***	-5.60***	-6.09***	-3.30**	-5.33***
Nigeria Commercial Hub (urban): Kano State	ADF	-2.89*	-6.95***	-2.62*	-2.82*	…	-5.69***
	PP	-3.70***	-7.06***	-5.42***	-5.16***	…	-5.86***
Urban-to-rural	ADF	-1.97	-3.01**	-4.66***	-3.78***	-0.63	-5.05***
	PP	-1.54	-5.08***	-4.61***	-4.41***	-2.87*	-4.95***

Note: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The unitary cointegration ADF and PP statistics test the stationarity of the price spreads. The price spread is equivalent to imposing the restriction $\beta = 1$ in the levels models. The null hypothesis for both the unitary cointegration ADF and PP tests is that the price spread is non-stationary. Rejection of non-stationarity of the price spread implies that it may be reasonable to assume $\beta = 1$ (Baffes, Kshirsagar, and Mitchell, 2015). The critical values for the unitary cointegration test ADF and PP statistics are, for n=100 are -3.50, -2.90, and -2.59; and, for n=50 are -3.59, -2.93, and -2.60, for the 1%, 5%, and 10% levels, respectively. All ADF and PP critical values are provided in Fuller (1996).

Table 3C-2: Unitary cointegration results for levels models for yams and cowpeas

Set	Cointegration statistic	Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Yams							
Neighbor country: Accra, Ghana	ADF	-4.14***	-4.28***	-3.80***	-0.64	-0.98	-3.60***
	PP	-5.27***	-4.04***	-3.19**	-3.12**	-4.58***	-3.67***
Nigeria Comm. Hub (urban): FCT (Abuja)	ADF	-1.98	-0.63	-5.40***	…	-1.18	-7.44***
	PP	-6.30***	-6.01***	-5.42***	…	-5.51***	-7.65***
Urban-to-rural	ADF	-4.86***	-1.43	-3.13**	-2.66*	-4.01***	-2.23
	PP	-4.85***	-3.88***	-3.79***	-2.73*	-4.05***	-4.39***
Cowpeas							
Neighbor country: Niamey, Niger	ADF	-2.26	-3.95***	-3.52***	-2.41	0.94	-3.05**
	PP	-2.81*	-6.85***	-3.50***	-2.54	-3.30**	-3.10**
Nigeria Commercial Hub (urban): Kano State	ADF	-2.51	-1.89	-5.47***	-2.52	…	-2.53
	PP	-7.26***	-5.52***	-5.54***	-6.60***	…	-7.34***
Urban-to-rural	ADF	-2.12	-4.93***	-4.55***	-2.49	-1.42	-6.30***
	PP	-1.75	-4.93***	-4.48***	-2.47	-3.66***	-6.75***

Note: a description of table contents is included below table 3C-1.

Appendix 3D. Comprehensive Levels Models Results

Table 3D-1: World maize price transmission levels model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
World Bank (US Gulf)	$\hat{\alpha}$	17.32*** (4.62)	27.91*** (6.61)	16.46*** (3.93)	16.49*** (4.58)	22.91*** (7.69)	23.89*** (6.56)
	$\hat{\beta}$	**2.54*** ** (12.89)	**2.49*** ** (11.26)	**2.81*** ** (12.78)	**1.96*** ** (10.36)	0.98*** (5.94)	1.11*** (6.07)
	$Adj.R^2$	0.58	0.51	0.58	0.47	0.24	0.25
	$ADF\ \hat{u}_t$	-3.15***	-2.67***	-3.77***	-2.70***	-3.24***	-3.60***
	PP $\hat{u}_t$	-3.84***	-5.20***	-3.78***	-2.93***	-3.31***	-3.51***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
IMF (US Gulf)	$\hat{\alpha}$	17.42*** (4.65)	28.00*** (6.64)	16.59*** (3.96)	16.52*** (4.60)	22.96*** (7.71)	23.96*** (6.60)
	$\hat{\beta}$	**2.53*** ** (12.88)	**2.49*** ** (11.25)	**2.80*** ** (12.76)	**1.96*** ** (10.38)	0.98*** (5.93)	1.11*** (6.06)
	$Adj.R^2$	0.58	0.51	0.58	0.47	0.24	0.25
	$ADF\ \hat{u}_t$	-3.17***	-2.67***	-3.75***	-2.70***	-3.25***	-3.61***
	PP $\hat{u}_t$	-3.83***	-5.20***	-3.77***	-2.93***	-3.32***	-3.52***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
GIEWS International (US Gulf)	$\hat{\alpha}$	17.16*** (4.57)	27.75*** (6.57)	16.33*** (3.89)	16.39*** (4.54)	23.01*** (7.70)	23.94*** (6.55)
	$\hat{\beta}$	**2.55*** ** (12.92)	**2.51*** ** (11.28)	**2.82*** ** (12.78)	**1.97*** ** (10.36)	0.98*** (5.89)	1.11*** (6.03)
	$Adj.R^2$	0.59	0.51	0.58	0.47	0.24	0.25
	$ADF\ \hat{u}_t$	-3.18***	-2.67***	-3.72***	-2.70***	-2.40**	-3.63***
	PP $\hat{u}_t$	-3.82***	-5.19***	-3.74***	-2.93***	-3.33***	-3.54***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
GIEWS International (Argentina)	$\hat{\alpha}$	19.20*** (5.57)	29.05*** (7.58)	17.55*** (4.70)	18.29*** (5.41)	24.24*** (9.00)	25.24*** (7.41)
	$\hat{\beta}$	**2.48*** ** (13.55)	**2.48*** ** (12.18)	**2.81*** ** (14.16)	**1.90*** ** (10.55)	0.91*** (6.14)	1.06*** (7.41)
	$Adj.R^2$	0.61	0.55	0.63	0.48	0.26	0.25
	$ADF\ \hat{u}_t$	-3.52***	-2.55**	-3.80***	-2.88***	-3.36***	-3.64***
	PP $\hat{u}_t$	-3.80***	-5.40***	-3.81***	-2.98***	-3.40***	-3.55***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
FAO (Argentina)	$\hat{\alpha}$	18.93*** (5.51)	28.87*** (7.53)	17.43*** (4.65)	18.08*** (5.35)	24.10*** (8.90)	24.98*** (7.34)
	$\hat{\beta}$	**2.50*** ** (13.67)	**2.49*** ** (12.21)	**2.82*** ** (14.14)	**1.91*** ** (10.63)	0.92*** (6.15)	1.08*** (6.20)
	$Adj.R^2$	0.61	0.55	0.63	0.48	0.26	0.26
	$ADF\ \hat{u}_t$	-3.55***	-2.57***	-3.84***	-2.84***	-2.40**	-3.62***
	PP $\hat{u}_t$	-3.82***	-5.45***	-3.85***	-3.01***	-3.40***	-3.53***
	$\hat{\gamma}$ significance	***	***	***	***	***	***

Note: t-statistics are in parentheses. ***, **, and * denote 1%, 5%, and 10% statistical significance, respectively. A **bold** EPT parameter ($\hat{\beta}$) signifies that it is statistically significantly greater than 1 at the 5% significance level. Critical values for the ADF and PP statistics associated with stationarity tests of estimated residuals ($\hat{u}_t$) for n=100 are -2.60, -1.95, and -1.61; for n=50 are -2.62, -1.95, and -1.60, for 1%, 5%, and 10% levels, respectively. All critical values are provided in Fuller (1996). A statistically significant estimated ECM term ($\hat{\gamma}$) implies cointegration (Banerjee et al. 1986).

cont. World maize price transmission levels model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
FAO (US Gulf)	$\hat{\alpha}$	16.99*** (4.52)	27.69*** (6.53)	16.31*** (3.86)	16.21*** (4.49)	22.88*** (7.60)	23.69*** (6.49)
	$\hat{\beta}$	**2.56***** (12.95)	**2.51***** (11.24)	**2.83***** (12.70)	**1.98***** (10.40)	0.99*** (5.89)	1.13*** (6.10)
	$Adj. R^2$	0.58	0.51	0.57	0.47	0.25	0.25
	$ADF\ \hat{u}_t$	-3.18***	-2.66***	-3.72***	-2.69***	-2.40**	-3.61***
	PP $\hat{u}_t$	-3.87***	-5.20***	-3.75***	-2.95***	-3.35***	-3.53***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
SAFEX	$\hat{\alpha}$	26.09*** (3.39)	37.35*** (4.54)	22.45*** (2.66)	33.94*** (4.49)	37.83*** (7.55)	35.63*** (6.35)
	$\hat{\beta}$	**1.71***** (5.26)	1.65*** (4.73)	**2.05***** (5.76)	0.82** (2.57)	0.13 (0.60)	0.40* (1.68)
	$Adj. R^2$	0.20	0.17	0.23	0.05	0.00	0.02
	$ADF\ \hat{u}_t$	-2.08**	-1.92*	-2.65***	-1.90*	-1.89**	-3.13***
	PP $\hat{u}_t$	-2.51**	-3.31***	-2.54**	-1.81*	-2.56**	-2.91***
	$\hat{\gamma}$ significance	***	***	***	***	***	***

The note below the first section of the table includes a description of table contents.

Table 3D-2: World rice price transmission levels model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
World Bank (Thai A1)	$\hat{\alpha}$	48.10***	56.30***	41.66***	50.63***	31.68***	62.04***
		(11.72)	(10.01)	(8.48)	(11.36)	(7.62)	(12.10)
	$\hat{\beta}$	**1.99*****	**2.28*****	**2.41*****	**2.19*****	**2.66*****	**1.95*****
		(18.02)	(15.01)	(18.22)	(18.20)	(21.52)	(14.71)
	$Adj.R^2$	0.73	0.65	0.74	0.74	0.81	0.67
	$ADF\ \hat{u}_t$	-3.10***	-1.90*	-3.13***	-2.01**	-2.00**	-4.61***
	PP $\hat{u}_t$	-4.78***	-4.28***	-3.95***	-3.53***	-3.32***	-3.94***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
FAO (Thai A1 Super)	$\hat{\alpha}$	48.81***	57.63***	42.93***	51.89***	32.22***	62.44***
		(12.23)	(10.36)	(8.86)	(11.76)	(7.69)	(12.70)
	$\hat{\beta}$	**1.95*****	**2.21*****	**2.34*****	**2.12*****	**2.63*****	**1.91*****
		(18.40)	(14.95)	(18.24)	(18.11)	(21.24)	(15.31)
	$Adj.R^2$	0.74	0.65	0.74	0.73	0.81	0.69
	$ADF\ \hat{u}_t$	-2.90***	-1.78*	-3.05***	-2.08**	-1.96**	-4.38***
	PP $\hat{u}_t$	-4.62***	-4.15***	-3.94***	-3.37***	-3.19***	-3.87***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
World Bank (Thai 5% broken)	$\hat{\alpha}$	49.73***	59.52***	41.45***	51.43***	39.81***	61.59***
		(15.08)	(11.92)	(12.12)	(15.37)	(12.60)	(16.12)
	$\hat{\beta}$	**1.44*****	**1.62*****	**1.79*****	**1.60*****	**1.78*****	**1.45*****
		(22.20)	(16.43)	(26.60)	(24.31)	(26.16)	(20.14)
	$Adj.R^2$	0.81	0.69	0.86	0.83	0.86	0.79
	$ADF\ \hat{u}_t$	-3.21***	-1.30	-2.41**	-1.75*	-1.35	-4.93***
	PP $\hat{u}_t$	-5.67***	-4.19***	-5.38***	-4.05***	-4.07***	-4.80***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
IMF (Thai 5% broken)	$\hat{\alpha}$	54.07***	64.84***	47.14***	56.53***	43.93***	66.84***
		(16.59)	(13.16)	(13.47)	(16.67)	(14.17)	(17.43)
	$\hat{\beta}$	**1.30*****	**1.44*****	**1.60*****	**1.43*****	**1.63*****	**1.29*****
		(21.25)	(15.64)	(24.50)	(22.61)	(25.45)	(18.79)
	$Adj.R^2$	0.79	0.67	0.83	0.81	0.86	0.77
	$ADF\ \hat{u}_t$	-3.09***	-1.25	-2.52**	-1.73*	-1.31	-4.77***
	PP $\hat{u}_t$	-5.50***	-4.01***	-5.10***	-3.93***	-3.86***	-4.60***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
World Bank (Thai 25% broken)	$\hat{\alpha}$	40.51***	45.96***	31.10***	41.96***	33.77***	48.04***
		(13.31)	(9.83)	(9.45)	(12.85)	(10.64)	(14.79)
	$\hat{\beta}$	**1.87*****	**2.20*****	**2.31*****	**2.06*****	**2.14*****	**1.99*****
		(26.46)	(20.20)	(30.11)	(27.19)	(27.78)	(27.54)
	$Adj.R^2$	0.86	0.78	0.89	0.87	0.88	0.88
	$ADF\ \hat{u}_t$	-2.65***	-5.62***	-6.09***	-1.50	-1.23	-4.50***
	PP $\hat{u}_t$	-5.98***	-5.70***	-6.08***	-4.94***	-4.30***	-6.87***
	$\hat{\gamma}$ significance	***	***	***	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

cont. World rice price transmission levels model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
GIEWS International (Thai 100% parboil)	$\hat{\alpha}$	55.28***	66.46***	49.00***	58.25***	46.77***	68.30***
		(17.31)	(13.62)	(13.95)	(17.11)	(14.15)	(19.32)
	$\hat{\beta}$	**1.24*** **	**1.38*** **	**1.53*** **	**1.37*** **	**1.53*** **	**1.24*** **
		(21.37)	(15.49)	(23.93)	(22.05)	(23.03)	(20.08)
	$Adj.R^2$	0.79	0.67	0.83	0.80	0.83	0.79
	$ADF\ \hat{u}_t$	-2.74***	-1.02	-2.47**	-1.75*	-1.40	-4.50***
	PP $\hat{u}_t$	-5.07***	-3.79***	-4.96***	-3.58***	-3.72***	-4.44***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
FAO (Thai 100%B 2nd grade)	$\hat{\alpha}$	51.78***	62.19***	44.50***	54.18***	42.62**	63.87***
		(16.47)	(12.80)	(13.24)	(16.47)	(13.40)	(17.69)
	$\hat{\beta}$	**1.34*** **	**1.49*** **	**1.66*** **	**1.48*** **	**1.65*** **	**1.34*** **
		(22.74)	(16.38)	(26.27)	(23.98)	(25.16)	(20.78)
	$Adj.R^2$	0.81	0.69	0.85	0.83	0.86	0.80
	$ADF\ \hat{u}_t$	-2.98***	-1.20	-2.65***	-1.80*	-1.26	-2.53**
	PP $\hat{u}_t$	-5.38***	-4.02***	-5.27***	-3.75***	-3.87***	-4.69***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
World Bank (Vietnam 5% broken)	$\hat{\alpha}$	57.08***	73.88***	56.19***	67.35***	58.92***	64.77***
		(12.91)	(9.12)	(8.68)	(11.12)	(9.69)	(12.12)
	$\hat{\beta}$	**1.61*** **	**1.74*** **	**1.86*** **	**1.64*** **	**1.73*** **	**1.72*** **
		(17.92)	(10.57)	(14.16)	(13.37)	(13.30)	(15.85)
	$Adj.R^2$	0.81	0.60	0.73	0.71	0.73	0.77
	$ADF\ \hat{u}_t$	-4.33***	-5.16***	-4.03***	-3.87***	-3.12***	-4.22***
	PP $\hat{u}_t$	-4.45***	-5.22***	-5.62***	-3.92***	-3.23***	-5.92***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
GIEWS International (Vietnam 5% broken)	$\hat{\alpha}$	49.78***	61.36***	43.37***	53.11***	30.36***	64.81***
		(12.77)	(10.56)	(9.42)	(12.23)	(7.60)	(13.23)
	$\hat{\beta}$	**1.62*** **	**1.77*** **	**1.97*** **	**1.76*** **	**2.28*** **	**1.56*** **
		(18.62)	(13.65)	(19.15)	(18.15)	(22.74)	(14.91)
	$Adj.R^2$	0.74	0.61	0.75	0.73	0.83	0.67
	$ADF\ \hat{u}_t$	-3.07***	-1.40	-2.66***	-1.91*	-1.38	-3.84***
	PP $\hat{u}_t$	-4.57***	-3.93***	-4.10***	-3.53***	-3.72***	-3.99***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
GIEWS International (Vietnam 25% broken)	$\hat{\alpha}$	49.24***	60.65***	43.21***	52.72***	29.84***	64.40***
		(12.47)	(10.35)	(9.09)	(11.90)	(7.41)	(12.71)
	$\hat{\beta}$	**1.78*** **	**1.95*** **	**2.15*** **	**1.93*** **	**2.49*** **	**1.71*** **
		(18.50)	(13.65)	(18.55)	(17.86)	(22.67)	(14.45)
	$Adj.R^2$	0.74	0.61	0.74	0.73	0.83	0.66
	$ADF\ \hat{u}_t$	-3.32***	-3.92***	-2.71***	-2.24**	-1.53	-2.63***
	PP $\hat{u}_t$	-4.63***	-4.01***	-4.00***	-3.58***	-3.82***	-3.95***
	$\hat{\gamma}$ significance	***	***	***	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

cont. World rice price transmission levels model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
GIEWS International (US)	$\hat{\alpha}$	36.27*** (8.68)	44.63*** (7.24)	26.41*** (5.50)	38.54*** (8.22)	18.31*** (3.84)	49.39*** (9.99)
	$\hat{\beta}$	**1.46***** (20.39)	**1.63***** (15.44)	**1.78***** (21.65)	**1.58***** (19.71)	**1.92***** (21.38)	**1.44***** (17.76)
	$Adj.R^2$	0.78	0.67	0.80	0.77	0.81	0.75
	$ADF\ \hat{u}_t$	-2.70***	-3.93***	-3.23***	-2.71***	-2.32**	-3.68***
	PP $\hat{u}_t$	-4.51***	-3.79***	-4.69***	-3.42***	-3.77***	-4.09***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
GIEWS International (Uruguay)	$\hat{\alpha}$	65.20*** (10.50)	87.97*** (6.78)	60.62*** (6.35)	87.64*** (11.48)	49.22*** (5.92)	70.45*** (8.15)
	$\hat{\beta}$	1.12*** (13.09)	1.12*** (6.23)	**1.38***** (10.46)	1.00*** (9.52)	**1.49***** (12.15)	1.21*** (10.15)
	$Adj.R^2$	0.74	0.39	0.65	0.60	0.76	0.63
	$ADF\ \hat{u}_t$	-3.85***	-3.19***	-4.04***	-2.48**	-3.67***	-3.74***
	PP $\hat{u}_t$	-3.85***	-3.13***	-4.02***	-3.90***	-3.59***	-3.76***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
GIEWS International (India 25% broken)	$\hat{\alpha}$	18.25** (2.51)	20.50** (2.49)	10.12 (1.48)	13.55** (2.08)	10.47 (1.45)	32.59*** (6.56)
	$\hat{\beta}$	**2.93***** (10.78)	**3.29***** (10.69)	**3.29***** (12.88)	**3.40***** (13.98)	**3.27***** (12.01)	**2.80***** (15.75)
	$Adj.R^2$	0.65	0.65	0.73	0.76	0.70	0.83
	$ADF\ \hat{u}_t$	-1.21	-1.04	-3.12***	-4.19***	-3.38***	-4.73***
	PP $\hat{u}_t$	-4.84***	-4.00***	-3.77***	-4.09***	-3.23***	-5.23***
	$\hat{\gamma}$ significance	***	***	***	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

Table 3D-3: World rice to local rice price transmission levels model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
World Bank (Thai A1)	$\hat{\alpha}$	35.78***	54.33***	37.99***	46.55***	27.44***	49.39***
		(8.12)	(10.81)	(9.96)	(11.19)	(10.77)	(11.42)
	$\hat{\beta}$	**1.91*** **	**1.39*** **	**1.58*** **	**1.51*** **	**1.64*** **	**1.25*** **
		(16.09)	(10.27)	(15.37)	(13.43)	(21.68)	(11.23)
	$Adj.R^2$	0.68	0.47	0.66	0.60	0.81	0.54
	$ADF\ \hat{u}_t$	-3.98***	-4.03***	-4.91***	-4.15***	-2.11**	-2.17**
	PP $\hat{u}_t$	-3.89***	-5.72***	-4.01***	-4.57***	-3.56***	-3.90***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
FAO (Thai A1 Super)	$\hat{\alpha}$	37.22***	55.39***	38.64***	47.10***	27.82***	49.86***
		(8.44)	(11.09)	(10.34)	(11.56)	(10.80)	(11.82)
	$\hat{\beta}$	**1.84*** **	**1.34*** **	**1.54*** **	**1.47*** **	**1.62*** **	**1.22*** **
		(15.75)	(10.13)	(15.54)	(13.61)	(21.28)	(11.43)
	$Adj.R^2$	0.68	0.46	0.67	0.61	0.81	0.55
	$ADF\ \hat{u}_t$	-3.94***	-3.99***	-2.98***	-4.47***	-2.32**	-2.15**
	PP $\hat{u}_t$	-3.85***	-5.63***	-4.03***	-4.57***	-3.50***	-3.76***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
World Bank (Thai 5% broken)	$\hat{\alpha}$	35.81***	55.20***	36.83***	46.40***	33.43***	48.60***
		(10.60)	(12.27)	(13.38)	(13.64)	(15.31)	(13.80)
	$\hat{\beta}$	**1.42*** **	1.01***	**1.20*** **	1.12***	1.07***	0.94***
		(21.27)	(11.42)	(22.07)	(16.71)	(22.84)	(14.22)
	$Adj.R^2$	0.79	0.52	0.80	0.70	0.83	0.66
	$ADF\ \hat{u}_t$	-2.40**	-6.08***	-5.98***	-5.27***	-1.59	-2.12**
	PP $\hat{u}_t$	-4.84***	-6.14***	-5.01***	-5.34***	-4.01***	-4.34***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
IMF (Thai 5% broken)	$\hat{\alpha}$	40.34***	58.54***	40.81***	50.14***	35.87***	51.99***
		(11.93)	(13.41)	(14.60)	(14.88)	(16.93)	(15.13)
	$\hat{\beta}$	**1.27*** **	0.90***	1.07***	1.00***	0.98***	0.84***
		(11.93)	(11.05)	(20.41)	(15.83)	(22.51)	(13.65)
	$Adj.R^2$	0.77	0.50	0.78	0.68	0.83	0.63
	$ADF\ \hat{u}_t$	-2.97***	-5.94***	-5.79***	-4.99***	-1.56	-2.09**
	PP $\hat{u}_t$	-4.68***	-6.00***	-4.75***	-5.04***	-3.98***	-4.26***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
World Bank (Thai 25% broken)	$\hat{\alpha}$	27.67***	44.88***	27.87***	36.58***	29.51***	38.60***
		(7.94)	(10.22)	(11.62)	(12.01)	(13.72)	(12.07)
	$\hat{\beta}$	**1.81*** **	**1.43*** **	**1.60*** **	**1.55*** **	**1.30*** **	**1.33*** **
		(22.35)	(14.03)	(28.68)	(21.82)	(24.89)	(18.79)
	$Adj.R^2$	0.81	0.63	0.88	0.81	0.85	0.78
	$ADF\ \hat{u}_t$	-1.60	-7.44***	-1.95**	-5.76***	-1.69*	-2.02**
	PP $\hat{u}_t$	-5.30***	-7.60***	-5.50***	-5.73***	-4.13***	-6.35***
	$\hat{\gamma}$ significance	***	***	***	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

cont. World rice to local rice price transmission levels model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
GIEWS International (Thai 100% parboil)	$\hat{\alpha}$	42.07***	59.55***	41.87***	51.00***	37.54***	53.30***
		(12.30)	(13.82)	(15.21)	(15.47)	(16.98)	(16.14)
	$\hat{\beta}$	**1.20*** **	0.86***	1.02***	0.96***	0.93***	0.80***
		(19.30)	(10.99)	(20.38)	(15.97)	(20.84)	(13.87)
	$Adj.R^2$	0.76	0.50	0.78	0.68	0.80	0.64
	$ADF\ \hat{u}_t$	-3.39***	-4.21***	-3.35***	-5.07***	-1.55	-2.07**
	PP $\hat{u}_t$	-4.31***	-5.87***	-4.79***	-5.09***	-3.83***	-4.11***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
FAO (Thai 100%B 2nd grade)	$\hat{\alpha}$	38.59***	57.19***	38.78***	48.01***	35.06***	50.24***
		(11.41)	(12.97)	(14.48)	(14.66)	(22.32)	(14.81)
	$\hat{\beta}$	**1.30*** **	0.93***	**1.11*** **	1.04***	1.00***	0.87***
		(20.49)	(11.23)	(22.04)	(16.95)	(22.32)	(14.34)
	$Adj.R^2$	0.78	0.51	0.80	0.71	0.82	0.66
	$ADF\ \hat{u}_t$	-1.94*	-5.99***	-5.61***	-5.24***	-1.56	-2.14***
	PP $\hat{u}_t$	-4.51***	-6.05***	-4.99***	-5.30***	-3.85***	-4.27***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
World Bank (Vietnam 5% broken)	$\hat{\alpha}$	57.35***	74.36***	47.17***	60.59***	46.74***	58.83***
		(10.19)	(9.40)	(8.51)	(10.38)	(10.69)	(11.26)
	$\hat{\beta}$	**1.30*** **	0.91***	**1.25*** **	1.12***	1.02***	1.00***
		(11.36)	(5.66)	(11.14)	(10.38)	(10.93)	(9.38)
	$Adj.R^2$	0.64	0.30	0.63	0.55	0.64	0.55
	$ADF\ \hat{u}_t$	-3.26***	-6.14***	-4.52***	-6.20***	-2.95***	-5.55***
	PP $\hat{u}_t$	-4.67***	-6.08***	-5.39***	-6.33***	-3.21***	-5.54***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
GIEWS International (Vietnam 5% broken)	$\hat{\alpha}$	37.60***	57.98***	39.44***	48.15***	27.79***	52.12***
		(8.87)	(9.41)	(10.76)	(11.92)	(10.28)	(12.26)
	$\hat{\beta}$	**1.55*** **	1.07***	**1.28*** **	**1.22*** **	**1.37*** **	0.98***
		(16.35)	(9.41)	(15.66)	(13.49)	(20.26)	(10.80)
	$Adj.R^2$	0.69	0.42	0.67	0.60	0.79	0.52
	$ADF\ \hat{u}_t$	-4.00***	-4.52***	-5.31***	-4.42***	-1.85*	-2.15**
	PP $\hat{u}_t$	-3.96***	-5.56***	-4.26***	-4.55***	-3.83***	-3.83***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
GIEWS International (Vietnam 25% broken)	$\hat{\alpha}$	37.21***	57.48***	39.50***	48.05***	27.50***	51.75***
		(8.64)	(11.22)	(10.46)	(11.67)	(10.07)	(11.91)
	$\hat{\beta}$	**1.70*** **	1.18***	**1.40*** **	**1.33*** **	**1.50*** **	1.08***
		(16.16)	(9.44)	(15.14)	(13.23)	(20.15)	(10.63)
	$Adj.R^2$	0.69	0.43	0.66	0.59	0.79	0.51
	$ADF\ \hat{u}_t$	-2.45***	-4.58***	-5.38***	-4.38***	-2.07**	-2.17**
	PP $\hat{u}_t$	-3.98***	-5.58***	-4.17***	-4.53***	-3.92***	-3.86***
	$\hat{\gamma}$ significance	***	***	***	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

cont. World rice to local rice price transmission levels model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
GIEWS International (US)	$\hat{\alpha}$	25.12***	47.16***	26.54***	35.41***	21.32***	42.44***
		(5.36)	(8.47)	(7.28)	(8.61)	(18.12)	(9.28)
	$\hat{\beta}$	**1.38*** **	1.00***	**1.19*** **	**1.14*** **	**1.14*** **	0.91***
		(17.26)	(10.46)	(19.14)	(16.23)	(18.12)	(12.07)
	$Adj. R^2$	0.71	0.48	0.76	0.69	0.75	0.57
	$ADF\ \hat{u}_t$	-2.88***	-5.85***	-4.25***	-4.99***	-3.44***	-3.91***
	PP $\hat{u}_t$	-3.88***	-5.87***	-4.30***	-5.01***	-3.77***	-3.83***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
GIEWS International (Uruguay)	$\hat{\alpha}$	65.51***	87.02***	62.92***	79.28***	35.35***	62.48***
		(7.41)	(7.52)	(8.43)	(10.37)	(5.86)	(6.31)
	$\hat{\beta}$	0.88***	0.51***	0.76***	0.61***	0.95***	0.69***
		(7.26)	(3.18)	(7.39)	(5.82)	(10.68)	(6.31)
	$Adj. R^2$	0.47	0.13	0.48	0.36	0.71	0.40
	$ADF\ \hat{u}_t$	-2.67***	-4.95***	-3.47***	-4.25***	-3.69***	-3.61***
	PP $\hat{u}_t$	-4.10***	-5.02***	-3.51***	-4.27***	-3.20***	-3.51***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
GIEWS International (India 25% broken)	$\hat{\alpha}$	2.34	19.57***	15.91***	12.12**	19.19***	19.84***
		(0.30)	(2.73)	(2.92)	(2.44)	(4.12)	(4.05)
	$\hat{\beta}$	**2.94*** **	**2.48*** **	**2.22*** **	**2.63*** **	**1.80*** **	**2.20*** **
		(10.09)	(9.27)	(10.93)	(14.18)	(10.27)	(12.57)
	$Adj. R^2$	0.62	0.58	0.66	0.77	0.64	0.76
	$ADF\ \hat{u}_t$	-2.49**	-3.10***	-3.30***	-2.92***	-3.56***	-4.66***
	PP $\hat{u}_t$	-3.55***	-5.50***	-3.23***	-3.93***	-3.47***	-4.72***
	$\hat{\gamma}$ significance	***	***	***	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

Table 3D-4: World sorghum price transmission levels model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
World Bank (US Gulf)	$\hat{\alpha}$	17.25***	6.80	7.86	13.82***	21.62***	26.06***
		(3.46)	(1.23)	(1.56)	(2.89)	(5.61)	(7.72)
	$\hat{\beta}$	**3.26*** **	**3.99*** **	**3.39*** **	**2.30*** **	1.03***	0.97***
		(11.85)	(13.13)	(12.24)	(8.72)	(4.60)	(5.40)
	$Adj. R^2$	0.54	0.59	0.56	0.39	0.16	0.21
	$ADF\ \hat{u}_t$	-2.79***	-2.00**	-3.06***	-2.68***	-2.58**	-3.02***
	PP $\hat{u}_t$	-3.69***	-3.63***	-3.47***	-2.80***	-3.03***	-2.81***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
FAO (US Gulf)	$\hat{\alpha}$	19.85***	8.82*	10.39**	15.30***	21.98***	25.62***
		(4.34)	(1.81)	(2.27)	(3.47)	(6.34)	(8.31)
	$\hat{\beta}$	**2.95*** **	**3.67*** **	**3.08*** **	**2.10*** **	0.95***	0.94***
		(12.39)	(14.49)	(12.92)	(9.16)	(5.05)	(6.09)
	$Adj. R^2$	0.56	0.64	0.58	0.41	0.19	0.25
	$ADF\ \hat{u}_t$	-2.72***	-3.67***	-2.78***	-2.99***	-2.56**	-3.07***
	PP $\hat{u}_t$	-3.62***	-3.66***	-3.40***	-2.78***	-3.02***	-2.89***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
GIEWS International (US Gulf)	$\hat{\alpha}$	19.10***	8.23*	9.67**	14.53***	21.75***	25.40***
		(4.18)	(1.68)	(2.11)	(3.30)	(6.27)	(8.21)
	$\hat{\beta}$	**3.00*** **	**3.72*** **	**3.13*** **	**2.15*** **	0.97***	0.96***
		(12.59)	(14.55)	(13.09)	(9.36)	(5.11)	(6.14)
	$Adj. R^2$	0.57	0.64	0.59	0.42	0.19	0.26
	$ADF\ \hat{u}_t$	-2.69***	-3.60***	-2.81***	-3.07***	-2.57**	-3.08***
	PP $\hat{u}_t$	-3.69***	-3.60***	-3.37***	-2.78***	-3.02***	-2.91***
	$\hat{\gamma}$ significance	***	***	***	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

Table 3D-5: World millet and cassava price transmission levels model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Millet							
World Bank (US Gulf)	$\hat{\alpha}$	14.37***	13.02**	-3.25	12.83***	21.11***	10.60**
		(2.93)	(2.28)	(-0.58)	(2.68)	(5.50)	(2.04)
	$\hat{\beta}$	**3.19***	**3.41***	**4.53***	**2.49***	1.10***	**1.90***
		(11.19)	(10.28)	(13.90)	(8.91)	(4.92)	(6.54)
	$Adj.R^2$	0.54	0.49	0.64	0.42	0.18	0.31
	$ADF\ \hat{u}_t$	-3.15***	-1.87*	-2.58**	-3.09***	-2.76***	-2.24**
	PP $\hat{u}_t$	-4.12***	-2.96***	-2.74***	-2.93***	-2.99***	-2.09**
	$\hat{\gamma}$ significance	***	**	**	**	**	*
FAO (US Gulf)	$\hat{\alpha}$	19.30***	15.36***	3.43	14.31***	21.73***	13.62***
		(4.30)	(3.14)	(0.68)	(3.44)	(6.29)	(2.88)
	$\hat{\beta}$	**2.73***	**3.08***	**3.88***	**2.26***	1.00***	**1.62***
		(11.20)	(11.60)	(14.09)	(9.99)	(6.29)	(6.58)
	$Adj.R^2$	0.54	0.56	0.65	0.48	0.20	0.31
	$ADF\ \hat{u}_t$	-3.12***	-1.89*	-2.34**	-2.83***	-3.26***	-2.28**
	PP $\hat{u}_t$	-4.06***	-2.93***	-2.29**	-2.96***	-3.01***	-2.10**
	$\hat{\gamma}$ significance	***	**	**	**	**	*
GIEWS International (US Gulf)	$\hat{\alpha}$	19.13***	15.55***	3.78	13.94***	21.55***	13.25***
		(4.24)	(3.13)	(0.78)	(3.35)	(6.22)	(2.81)
	$\hat{\beta}$	**2.74***	**3.08***	**3.87***	**2.28***	1.01***	**1.65***
		(11.17)	(11.38)	(13.71)	(10.09)	(5.37)	(6.67)
	$Adj.R^2$	0.54	0.55	0.64	0.49	0.21	0.31
	$ADF\ \hat{u}_t$	-3.17***	-1.87*	-1.39	-2.24**	-3.29***	-2.28**
	PP $\hat{u}_t$	-4.15***	-2.92***	-2.32**	-3.03***	-3.03***	-2.18**
	$\hat{\gamma}$ significance	***	**	**	***	**	**
Cassava							
GIEWS Domestic (Bangkok, Thailand)	$\hat{\alpha}$	38.04***	53.06***	44.62***	35.93***	31.49***	58.21***
		(14.28)	(17.53)	(16.23)	(12.83)	(11.12)	(23.38)
	$\hat{\beta}$	0.95***	0.80***	0.85***	0.97***	1.02***	0.70***
		(13.11)	(9.69)	(11.39)	(12.66)	(13.25)	(10.75)
	$Adj.R^2$	0.59	0.44	0.52	0.57	0.59	0.52
	$ADF\ \hat{u}_t$	-3.17***	-2.48**	-5.31***	-2.88***	-3.41***	-4.09***
	PP $\hat{u}_t$	-4.23***	-6.52***	-5.40***	-3.48***	-3.14***	-4.96***
	$\hat{\gamma}$ significance	***	**	**	***	**	**

Note: a description of table contents is included below the first section of table 3D-1.

Table 3D-6: Neighboring country maize price transmission levels model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Randfontein, South Africa	$\hat{\alpha}$	20.40***	29.35***	15.47**	30.28***	31.21***	34.40***
		(3.35)	(4.57)	(2.39)	(5.12)	(7.69)	(6.18)
	$\hat{\beta}$	**1.93*** **	**1.97*** **	**2.34*** **	0.97***	0.39**	0.45*
		(7.22)	(6.98)	(8.21)	(3.73)	(2.14)	(1.92)
	$Adj.R^2$	0.30	0.29	0.36	0.10	0.03	0.02
	$ADF\ \hat{u}_t$	-2.35**	-2.09**	-2.96***	-2.05**	-2.21***	-3.12***
	PP $\hat{u}_t$	-2.79***	-3.64***	-2.93***	-2.02**	-3.06***	-2.91***
	$\hat{\gamma}$ significance	**	***	**	*	***	***
Cotonou, Benin	$\hat{\alpha}$	25.07***	37.33***	30.00***	17.42***	16.74***	20.64***
		(7.49)	(9.54)	(7.09)	(6.62)	(9.22)	(7.93)
	$\hat{\beta}$	0.81***	0.76***	0.79***	0.74***	0.52***	0.50***
		(12.26)	(9.79)	(9.46)	(14.14)	(13.65)	(10.02)
	$Adj.R^2$	0.56	0.44	0.43	0.63	0.63	0.48
	$ADF\ \hat{u}_t$	-1.73*	-1.73*	-2.01**	-1.25	-5.37***	-5.16***
	PP $\hat{u}_t$	-4.10***	-4.91***	-3.15***	-4.20***	-5.37***	-5.23***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Malanville, Benin	$\hat{\alpha}$	28.62***	40.08***	31.01***	20.68***	12.82***	20.43***
		(8.40)	(8.88)	(6.70)	(7.41)	(6.81)	(8.67)
	$\hat{\beta}$	0.97***	0.97***	1.04***	0.91***	0.90***	0.69***
		(9.66)	(7.23)	(7.58)	(11.07)	(14.43)	(10.36)
	$Adj.R^2$	0.48	0.34	0.36	0.55	0.70	0.55
	$ADF\ \hat{u}_t$	1.64*	-0.51	-0.01	-0.43	-5.79***	-4.83***
	PP $\hat{u}_t$	-3.96***	-3.84***	-2.79***	-3.53***	-5.95***	-4.90***
	$\hat{\gamma}$ significance	***	***	**	***	***	***
Accra, Ghana	$\hat{\alpha}$	30.53***	57.10***	64.90***	9.90	16.54***	19.00***
		(4.70)	(7.47)	(9.30)	(1.52)	(4.07)	(3.57)
	$\hat{\beta}$	0.97***	0.65***	0.46***	1.05***	0.60***	0.63***
		(7.73)	(4.40)	(3.39)	(8.30)	(7.35)	(6.14)
	$Adj.R^2$	0.50	0.24	0.15	0.53	0.53	0.38
	$ADF\ \hat{u}_t$	-3.79***	-0.72	-1.56	-0.83	-3.42***	-4.06***
	PP $\hat{u}_t$	-3.85***	-4.83***	-3.94***	-3.09***	-3.46***	-4.04***
	$\hat{\gamma}$ significance	***	***	***		***	***
Bolgatanga, Ghana	$\hat{\alpha}$	37.72***	62.45***	74.87***	19.49***	22.41***	24.54***
		(6.07)	(8.80)	(11.17)	(2.99)	(5.64)	(4.83)
	$\hat{\beta}$	1.04***	0.68***	0.32**	1.07***	0.61***	0.66***
		(6.94)	(3.99)	(2.00)	(6.83)	(6.06)	(5.35)
	$Adj.R^2$	0.44	0.20	0.05	0.44	0.43	0.32
	$ADF\ \hat{u}_t$	-1.54	-0.48	-1.21	-1.32	-3.35***	-3.43***
	PP $\hat{u}_t$	-3.04***	-4.33***	-3.58***	-2.44**	-3.33***	-3.41***
	$\hat{\gamma}$ significance	***	***	***	**	***	***

Note: a description of table contents is included below the first section of table 3D-1.

cont. Neighboring country maize price transmission levels model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Lomé, Togo	$\hat{\alpha}$	24.29*** (10.69)	35.83*** (12.35)	29.28*** (8.89)	20.35*** (9.18)	20.19*** (13.05)	20.95*** (9.97)
	$\hat{\beta}$	0.88*** (18.87)	0.84*** (14.09)	0.86*** (12.69)	0.72*** (15.69)	0.47*** (14.01)	0.52*** (12.47)
	$Adj.R^2$	0.75	0.62	0.57	0.67	0.65	0.59
	$ADF\ \hat{u}_t$	-5.33***	-1.89*	-2.96***	-1.62*	-5.04***	-5.66***
	PP $\hat{u}_t$	-5.37***	-6.98***	-4.40***	-4.96***	-5.10***	-5.66***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Korbongou, Togo	$\hat{\alpha}$	27.44*** (8.28)	38.19*** (10.28)	31.71*** (7.75)	20.34*** (7.48)	16.03*** (10.75)	21.34*** (8.96)
	$\hat{\beta}$	1.16*** (11.69)	1.13*** (10.14)	1.15*** (9.39)	1.02*** (12.60)	0.83*** (17.24)	0.73*** (10.73)
	$Adj.R^2$	0.53	0.46	0.42	0.57	0.73	0.52
	$ADF\ \hat{u}_t$	-4.15***	-0.81	-1.84*	-1.92*	-2.80***	-5.00***
	PP $\hat{u}_t$	-4.19***	-5.20***	-3.41***	-4.07***	-6.95***	-5.10***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Niamey, Niger	$\hat{\alpha}$	9.83*** (3.19)	22.70*** (5.72)	14.94*** (3.42)	6.69** (2.48)	10.95*** (6.25)	8.96*** (3.61)
	$\hat{\beta}$	**1.19***** (18.25)	1.12*** (13.31)	1.17*** (12.58)	1.01*** (17.66)	0.67*** (17.38)	0.77*** (15.17)
	$Adj.R^2$	0.74	0.60	0.57	0.72	0.74	0.68
	$ADF\ \hat{u}_t$	-4.81***	-1.38	-2.03**	-4.74***	-4.06***	-4.98***
	PP $\hat{u}_t$	-4.85***	-6.11***	-3.54***	-4.68***	-5.70***	-5.79***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Maradi, Niger	$\hat{\alpha}$	13.28*** (4.20)	24.99*** (6.49)	17.38*** (4.09)	8.60*** (3.30)	10.58*** (7.10)	11.05*** (4.88)
	$\hat{\beta}$	**1.15***** (16.66)	1.11*** (13.15)	1.15*** (12.40)	1.00*** (17.56)	0.71*** (20.76)	0.75*** (15.77)
	$Adj.R^2$	0.70	0.59	0.56	0.72	0.80	0.70
	$ADF\ \hat{u}_t$	-4.36***	-2.00**	-3.53***	-2.73***	-4.47***	-4.91***
	PP $\hat{u}_t$	-4.38***	-6.03***	-1.96**	-4.56***	-6.81***	-5.73***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
N'Djamena, Chad	$\hat{\alpha}$	15.15*** (2.99)	35.40*** (5.43)	25.95*** (3.81)	4.91 (0.99)	10.02*** (3.65)	10.33*** (2.94)
	$\hat{\beta}$	1.04*** (11.28)	0.85*** (7.26)	0.93*** (7.61)	0.97*** (10.82)	0.63*** (12.62)	0.70*** (11.06)
	$Adj.R^2$	0.60	0.38	0.40	0.57	0.68	0.59
	$ADF\ \hat{u}_t$	-3.59***	-1.02	-3.05***	-2.29**	-4.82***	-4.40***
	PP $\hat{u}_t$	-3.48***	-4.91***	-2.80***	-2.78***	-4.73***	-5.00***
	$\hat{\gamma}$ significance	***	***	***	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

cont. Neighboring country maize price transmission levels model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Yaoundé, Cameroon	$\hat{\alpha}$	27.90*** (5.82)	41.08*** (8.70)	35.35*** (7.23)	16.90*** (3.24)	29.12*** (7.40)	25.62*** (5.80)
	$\hat{\beta}$	0.74*** (10.44)	0.70*** (10.13)	0.73*** (10.11)	0.68*** (8.84)	0.26*** (4.66)	0.38*** (5.87)
	$Adj.R^2$	0.60	0.59	0.59	0.52	0.26	0.32
	$ADF\ \hat{u}_t$	-3.60***	-7.06***	-4.97***	-2.38**	-3.12***	-3.96***
	PP $\hat{u}_t$	-3.58***	-7.10***	-4.97***	-2.59**	-3.13***	-3.91***
	$\hat{\gamma}$ significance	***	***	***		***	***
Garoua, Cameroon	$\hat{\alpha}$	32.82*** (4.44)	45.82*** (6.36)	44.96*** (5.75)	10.21 (1.58)	14.24*** (4.24)	14.28*** (3.10)
	$\hat{\beta}$	0.85*** (5.99)	0.81*** (5.88)	0.74*** (4.97)	1.00*** (8.10)	0.63*** (9.95)	0.71*** (8.10)
	$Adj.R^2$	0.33	0.32	0.25	0.48	0.62	0.48
	$ADF\ \hat{u}_t$	-2.97***	-3.53***	-2.73***	-2.21**	-2.32**	-2.90***
	PP $\hat{u}_t$	-2.89***	-5.34***	-3.30***	-2.36**	-3.81***	-4.33***
	$\hat{\gamma}$ significance	***	***	***	**	***	***
Bamako, Mali	$\hat{\alpha}$	29.09*** (3.28)	38.67*** (4.38)	41.54*** (4.93)	4.14 (0.46)	5.47 (1.65)	6.97 (0.94)
	$\hat{\beta}$	1.13*** (6.36)	1.12*** (6.35)	0.98*** (5.84)	1.29*** (7.10)	0.85*** (13.10)	0.94*** (6.33)
	$Adj.R^2$	0.46	0.46	0.41	0.51	0.83	0.45
	$ADF\ \hat{u}_t$	-2.87***	-4.92***	-2.14***	-2.68***	-3.88***	-3.41***
	PP $\hat{u}_t$	-2.95***	-4.92***	-4.61***	-2.08**	-2.87***	-3.42***
	$\hat{\gamma}$ significance	***	***	***		***	***
Mopti, Mali	$\hat{\alpha}$	14.49*** (2.95)	27.96*** (5.11)	21.72*** (3.49)	1.94 (0.46)	9.48*** (3.67)	10.12*** (2.96)
	$\hat{\beta}$	**1.44***** (11.35)	**1.36***** (9.63)	**1.38***** (8.61)	**1.41***** (13.11)	0.86*** (12.90)	0.96*** (10.92)
	$Adj.R^2$	0.58	0.49	0.44	0.65	0.67	0.56
	$ADF\ \hat{u}_t$	-4.26***	-0.65	-1.84*	-3.12***	-3.53***	-5.35***
	PP $\hat{u}_t$	-4.24***	-5.10***	-3.72***	-3.93***	-5.24***	-5.37***
	$\hat{\gamma}$ significance	***	***	***	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

Table 3D-7: Neighboring country rice price transmission levels model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
Cotonou, Benin	$\hat{\alpha}$	24.88*** (5.50)	26.15** (4.46)	12.56** (2.42)	24.47*** (5.14)	21.88*** (4.59)	34.18*** (6.76)
	$\hat{\beta}$	0.93*** (21.19)	1.10*** (19.33)	**1.14***** (22.53)	1.03*** (22.24)	0.98*** (20.63)	0.96*** (20.25)
	$Adj. R^2$	0.79	0.76	0.81	0.81	0.80	0.79
	$ADF\ \hat{u}_t$	-2.10**	-4.86***	-2.07**	-1.22	-0.89	-3.10***
	PP $\hat{u}_t$	-4.77***	-4.76***	-5.05***	-3.55***	-3.40***	-4.48***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Accra, Ghana	$\hat{\alpha}$	29.47** (2.51)	13.94 (0.68)	12.00 (0.65)	43.64*** (3.52)	14.31 (0.84)	13.84 (1.07)
	$\hat{\beta}$	0.92*** (10.36)	1.21*** (7.77)	1.16*** (8.40)	0.91*** (9.74)	1.08*** (8.27)	1.13*** (11.60)
	$Adj. R^2$	0.68	0.55	0.59	0.66	0.65	0.73
	$ADF\ \hat{u}_t$	-2.95***	-3.96***	-3.87***	-2.70***	-2.47**	-4.05***
	PP $\hat{u}_t$	-2.92***	-4.10***	-3.89***	-2.66***	-2.45**	-4.85***
	$\hat{\gamma}$ significance	***	***	***	**	**	***
Bolgatanga, Ghana	$\hat{\alpha}$	44.91** (2.37)	-3.49 (-0.15)	26.30 (0.99)	70.03*** (3.45)	24.48 (1.10)	20.66 (1.01)
	$\hat{\beta}$	0.95*** (5.56)	**1.58***** (7.65)	1.26*** (5.25)	0.84*** (4.59)	1.19*** (5.88)	1.29*** (7.00)
	$Adj. R^2$	0.38	0.55	0.36	0.29	0.48	0.50
	$ADF\ \hat{u}_t$	-3.21***	-4.01***	-2.15**	-2.99***	-2.43**	-2.57**
	PP $\hat{u}_t$	-3.12***	-4.13***	-3.99***	-2.91***	-2.29**	-4.58***
	$\hat{\gamma}$ significance	***	***	***			**
Lomé, Togo	$\hat{\alpha}$	56.59*** (14.40)	65.70*** (12.48)	53.21*** (10.84)	59.90*** (14.05)	54.91*** (11.89)	71.51*** (16.65)
	$\hat{\beta}$	0.67*** (16.83)	0.77*** (14.40)	0.80*** (16.00)	0.74*** (17.02)	0.72*** (14.54)	0.65*** (15.64)
	$Adj. R^2$	0.70	0.63	0.68	0.71	0.66	0.69
	$ADF\ \hat{u}_t$	-2.78***	-3.08***	-2.14**	-1.67*	-3.64***	-3.00***
	PP $\hat{u}_t$	-5.27***	-5.01***	-6.15***	-4.67***	-3.75***	-5.73***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Korbongou, Togo	$\hat{\alpha}$	24.70*** (5.34)	27.82*** (4.23)	9.07* (1.87)	22.81*** (5.04)	19.51*** (4.19)	32.97*** (5.88)
	$\hat{\beta}$	1.10*** (20.43)	**1.28***** (16.73)	**1.38***** (24.54)	**1.23***** (23.39)	**1.17***** (21.27)	**1.14***** (18.20)
	$Adj. R^2$	0.78	0.71	0.84	0.82	0.81	0.76
	$ADF\ \hat{u}_t$	-2.62***	-4.41***	-2.34**	-2.02**	-1.20	-2.68***
	PP $\hat{u}_t$	-6.09***	-4.18***	-6.68***	-5.53***	-4.24***	-4.09***
	$\hat{\gamma}$ significance	***	***	***	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

cont. Neighboring country rice price transmission levels model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Ouagadougou, Burkina Faso	$\hat{\alpha}$	62.65*** (10.97)	82.79*** (6.63)	54.43*** (6.46)	79.93*** (12.84)	57.55*** (9.34)	63.09*** (8.69)
	$\hat{\beta}$	0.94*** (14.70)	0.97*** (6.91)	**1.19***** (12.60)	0.90*** (12.97)	1.05*** (15.12)	1.07*** (13.12)
	$Adj.R^2$	0.78	0.44	0.73	0.74	0.83	0.74
	$ADF\ \hat{u}_t$	-5.76***	-3.54***	-6.43***	-5.74***	-3.52***	-5.51***
	PP $\hat{u}_t$	-5.86***	-3.53***	-6.41***	-5.76***	-4.23***	-5.63***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Dori, Burkina Faso	$\hat{\alpha}$	55.68*** (9.46)	69.65*** (5.59)	42.80*** (5.29)	71.42*** (11.88)	52.06*** (8.70)	53.28*** (7.54)
	$\hat{\beta}$	0.93*** (15.42)	1.02*** (7.98)	**1.21***** (14.56)	0.91*** (14.82)	1.01*** (16.47)	1.08*** (14.87)
	$Adj.R^2$	0.80	0.51	0.78	0.79	0.85	0.79
	$ADF\ \hat{u}_t$	-4.99***	-3.67***	-5.86***	-5.93***	-4.95***	-5.24***
	PP $\hat{u}_t$	-4.99***	-3.67***	-5.84***	-5.89***	-4.88***	-5.38***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Niamey, Niger	$\hat{\alpha}$	15.42*** (4.00)	17.65*** (3.07)	0.21 (0.05)	13.57*** (3.55)	9.51** (2.53)	20.66*** (4.73)
	$\hat{\beta}$	**1.18***** (27.33)	**1.36***** (21.17)	**1.45***** (31.99)	**1.31***** (30.57)	**1.28***** (29.41)	**1.25***** (26.50)
	$Adj.R^2$	0.86	0.79	0.90	0.89	0.89	0.87
	$ADF\ \hat{u}_t$	-3.00***	-3.67***	-7.07***	-5.26***	-1.81*	-3.68***
	PP $\hat{u}_t$	-6.86***	-5.14***	-7.00***	-5.20***	-4.74***	-6.52***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Maradi, Niger	$\hat{\alpha}$	31.26*** (8.66)	35.56*** (6.90)	20.16*** (5.02)	30.99*** (8.59)	26.57*** (8.21)	40.83*** (9.78)
	$\hat{\beta}$	0.92*** (25.01)	1.07*** (20.47)	**1.13***** (27.53)	1.02*** (27.79)	0.99*** (29.31)	0.95*** (23.11)
	$Adj.R^2$	0.84	0.78	0.86	0.87	0.89	0.83
	$ADF\ \hat{u}_t$	-2.52***	-3.60***	-2.34**	-1.55	-1.29	-3.51***
	PP $\hat{u}_t$	-5.84***	-4.95***	-5.98***	-4.47***	-4.70***	-5.25***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
N'Djamena, Chad	$\hat{\alpha}$	33.20*** (2.86)	55.00*** (3.50)	18.63 (1.39)	38.50*** (3.04)	26.61* (1.98)	35.53*** (2.96)
	$\hat{\beta}$	0.84*** (8.64)	0.83*** (6.36)	1.05*** (9.46)	0.88*** (8.39)	0.93*** (8.11)	0.91*** (9.12)
	$Adj.R^2$	0.46	0.31	0.51	0.45	0.47	0.49
	$ADF\ \hat{u}_t$	-1.42	-2.18**	-1.17	-2.96***	-3.25***	-2.58**
	PP $\hat{u}_t$	-4.99***	-3.77***	-5.17***	-3.98***	-4.31***	-4.70***
	$\hat{\gamma}$ significance	***	***	***	**	***	***

Note: a description of table contents is included below the first section of table 3D-1.

cont. Neighboring country rice price transmission levels model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Yaoundé, Cameroon	$\hat{\alpha}$	55.45*** (7.02)	60.63*** (5.41)	34.75*** (3.90)	57.93*** (9.29)	54.80*** (8.04)	54.39*** (6.86)
	$\hat{\beta}$	0.81*** (11.60)	0.95*** (9.17)	1.10*** (13.37)	0.89*** (15.50)	0.84*** (13.35)	0.91*** (12.45)
	$Adj.R^2$	0.65	0.54	0.71	0.77	0.75	0.68
	$ADF\ \hat{u}_t$	-5.41***	-3.82***	-5.42***	-5.28***	-4.26***	-2.72***
	PP $\hat{u}_t$	-5.46***	-3.83***	-5.49***	-5.25***	-4.28***	-4.23***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Garoua, Cameroon	$\hat{\alpha}$	34.35*** (4.27)	43.53*** (3.35)	14.09 (1.38)	41.08*** (5.81)	35.81*** (4.89)	36.87*** (4.09)
	$\hat{\beta}$	0.94*** (13.30)	1.05*** (9.17)	**1.22***** (13.67)	0.99*** (16.00)	0.98*** (14.98)	1.02*** (12.85)
	$Adj.R^2$	0.71	0.54	0.72	0.78	0.79	0.70
	$ADF\ \hat{u}_t$	-6.13***	-4.06***	-5.89***	-4.88***	-5.13***	-3.43***
	PP $\hat{u}_t$	-6.16***	-4.08***	-5.89***	-6.01***	-5.11***	-4.69***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Bamako, Mali	$\hat{\alpha}$	34.00*** (3.95)	44.72*** (2.72)	13.14 (1.16)	48.15*** (5.83)	23.89** (2.62)	27.74*** (2.74)
	$\hat{\beta}$	**1.28***** (12.99)	**1.42***** (7.53)	**1.68***** (12.93)	**1.28***** (13.53)	**1.45***** (13.78)	**1.49***** (12.80)
	$Adj.R^2$	0.74	0.49	0.74	0.76	0.80	0.73
	$ADF\ \hat{u}_t$	-3.05***	-3.63***	-6.26***	-6.72***	-2.43**	-5.40***
	PP $\hat{u}_t$	-5.36***	-3.58***	-6.25***	-6.68***	-4.59***	-5.53***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Mopti, Mali	$\hat{\alpha}$	41.35*** (4.43)	38.76* (1.75)	7.85 (0.56)	45.79*** (5.41)	13.72 (1.33)	35.34*** (2.72)
	$\hat{\beta}$	**1.22***** (11.95)	**1.48***** (6.14)	**1.75***** (11.47)	**1.31***** (14.23)	**1.56***** (14.01)	**1.42***** (10.03)
	$Adj.R^2$	0.75	0.44	0.74	0.81	0.85	0.68
	$ADF\ \hat{u}_t$	-3.17***	-2.44**	-5.61***	-4.80***	-4.74***	-2.32**
	PP $\hat{u}_t$	-4.55***	-2.38**	-5.67***	-4.67***	-3.91***	-4.21***
	$\hat{\gamma}$ significance	***	**	***	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

Table 3D-8: Neighboring country rice to local rice price transmission levels model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
Cotonou, Benin	$\hat{\alpha}$	12.20** (2.56)	33.16** (6.03)	16.94** (4.33)	26.21*** (5.87)	21.47*** (7.30)	28.30*** (6.59)
	$\hat{\beta}$	0.91*** (19.58)	0.70*** (13.12)	0.77*** (20.13)	0.73*** (16.90)	0.60*** (20.62)	0.65*** (16.12)
	$Adj. R^2$	0.76	0.59	0.77	0.71	0.80	0.71
	$ADF\ \hat{u}_t$	-2.68***	-6.52***	-2.33**	-3.82***	-1.37	-4.75***
	PP $\hat{u}_t$	-4.10***	-6.61***	-4.34***	-5.19***	-3.65***	-4.74***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Accra, Ghana	$\hat{\alpha}$	21.56 (1.41)	41.47* (1.96)	79.73 (1.49)	49.37*** (3.95)	0.68 (0.07)	40.15*** (2.76)
	$\hat{\beta}$	0.84*** (7.28)	0.64*** (4.00)	0.76*** (7.62)	0.59*** (6.25)	0.79*** (10.12)	0.57*** (0.57)
	$Adj. R^2$	0.51	0.23	0.54	0.44	0.73	0.35
	$ADF\ \hat{u}_t$	-2.08**	-4.34***	-3.70***	-4.65***	-3.03***	-3.49***
	PP $\hat{u}_t$	-3.32***	-4.70***	-3.73***	-4.64***	-3.19***	-3.40***
	$\hat{\gamma}$ significance	***	***	***	***	**	***
Bolgatanga, Ghana	$\hat{\alpha}$	19.66 (1.00)	23.06 (0.97)	19.13 (1.10)	74.94*** (4.21)	22.35 (1.38)	46.75** (2.54)
	$\hat{\beta}$	1.02*** (5.73)	0.92*** (4.30)	0.92*** (5.83)	0.47*** (2.91)	0.73*** (4.93)	0.62*** (3.72)
	$Adj. R^2$	0.40	0.27	0.41	0.13	0.39	0.21
	$ADF\ \hat{u}_t$	-1.16	-5.44***	-2.33**	-4.32***	-2.94***	-3.61***
	PP $\hat{u}_t$	-2.95***	-5.43***	-4.11***	-4.26***	-2.91***	-3.55***
	$\hat{\gamma}$ significance	***	***	***	***	**	**
Lomé, Togo	$\hat{\alpha}$	44.52*** (10.44)	59.79*** (12.96)	43.25*** (12.76)	51.73*** (13.83)	41.60*** (14.81)	53.16*** (15.76)
	$\hat{\beta}$	0.63*** (14.70)	0.47*** (10.11)	0.55*** (15.96)	0.52*** (13.73)	0.45*** (14.81)	0.45*** (13.59)
	$Adj. R^2$	0.64	0.46	0.68	0.61	0.67	0.63
	$ADF\ \hat{u}_t$	-2.19**	-4.00***	-3.53***	-3.66***	-1.46	-2.59**
	PP $\hat{u}_t$	-4.18***	-6.52***	-5.68***	-5.63***	-3.63***	-6.00***
	$\hat{\gamma}$ significance	***	***	***	***	**	***
Korbongou, Togo	$\hat{\alpha}$	11.39** (2.28)	32.45*** (5.70)	14.44*** (3.88)	23.40*** (5.46)	21.63*** (6.83)	28.80*** (6.18)
	$\hat{\beta}$	1.08*** (18.65)	0.84*** (12.64)	0.93*** (21.61)	0.90*** (18.07)	0.70*** (18.67)	0.75*** (14.43)
	$Adj. R^2$	0.75	0.58	0.80	0.74	0.77	0.67
	$ADF\ \hat{u}_t$	-3.42***	-2.50**	-5.12***	-4.41***	-3.92***	-5.70***
	PP $\hat{u}_t$	-5.04***	-6.81***	-5.11***	-6.76***	-3.85***	-5.82***
	$\hat{\gamma}$ significance	***	***	***	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

cont. Neighboring country rice to local rice price transmission levels model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
Ouagadougou, Burkina Faso	$\hat{\alpha}$	51.52*** (7.77)	74.69*** (6.93)	54.58*** (8.74)	73.41*** (10.44)	42.78*** (8.16)	55.69*** (7.85)
	$\hat{\beta}$	0.88*** (11.86)	0.56*** (4.60)	0.71*** (10.20)	0.57*** (7.20)	0.65*** (10.93)	0.64*** (8.00)
	$Adj. R^2$	0.70	0.25	0.64	0.46	0.72	0.52
	$ADF\ \hat{u}_t$	-4.73***	-5.45***	-4.51***	-5.52***	-1.74*	-5.01***
	PP $\hat{u}_t$	-6.09***	-5.47***	-4.81***	-5.60***	-3.29***	-4.94***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Dori, Burkina Faso	$\hat{\alpha}$	45.23*** (6.48)	66.28*** (5.96)	48.42*** (7.56)	65.39*** (9.45)	37.96*** (7.77)	47.00*** (6.82)
	$\hat{\beta}$	0.87*** (12.15)	0.60*** (5.22)	0.72*** (10.90)	0.60*** (8.47)	0.64*** (12.72)	0.67*** (9.51)
	$Adj. R^2$	0.71	0.31	0.67	0.55	0.77	0.60
	$ADF\ \hat{u}_t$	-5.78***	-5.75***	-4.21***	-4.65***	-2.44**	-5.04***
	PP $\hat{u}_t$	-5.88***	-5.77***	-4.29***	-5.54***	-3.71***	-4.96***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Niamey, Niger	$\hat{\alpha}$	1.03 (0.28)	25.67*** (4.81)	7.69** (2.52)	17.46*** (4.48)	14.93*** (5.71)	20.00*** (4.72)
	$\hat{\beta}$	**1.17*** ** (27.89)	0.89*** (14.91)	0.99*** (28.79)	0.94*** (21.57)	0.77*** (25.62)	0.83*** (18.27)
	$Adj. R^2$	0.87	0.65	0.87	0.80	0.86	0.76
	$ADF\ \hat{u}_t$	-3.83***	-6.99***	-5.62***	-6.12***	-3.91***	-5.64***
	PP $\hat{u}_t$	-6.13***	-7.03***	-5.63***	-6.17***	-4.07***	-5.69***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Maradi, Niger	$\hat{\alpha}$	16.80*** (4.76)	37.24*** (7.93)	21.83*** (7.06)	30.71*** (8.38)	25.28*** (11.23)	31.94*** (9.02)
	$\hat{\beta}$	0.92*** (25.34)	0.70*** (14.63)	0.76*** (24.12)	0.73*** (19.52)	0.60*** (25.49)	0.65*** (18.66)
	$Adj. R^2$	0.84	0.64	0.83	0.76	0.86	0.76
	$ADF\ \hat{u}_t$	-3.20***	-6.97***	-2.77***	-5.69***	-2.44***	-5.66***
	PP $\hat{u}_t$	-5.37***	-7.01***	-4.74***	-5.73***	-4.24***	-5.70***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
N'Djamena, Chad	$\hat{\alpha}$	31.52*** (2.83)	55.57*** (4.40)	23.43** (2.28)	37.06*** (3.53)	25.07*** (2.77)	29.17*** (3.28)
	$\hat{\beta}$	0.73*** (7.85)	0.50*** (4.80)	0.69*** (8.04)	0.63*** (7.18)	0.56*** (7.30)	0.62*** (8.41)
	$Adj. R^2$	0.41	0.20	0.43	0.37	0.41	0.45
	$ADF\ \hat{u}_t$	-3.30***	-6.01***	-1.54	-3.58***	-1.31	-2.58**
	PP $\hat{u}_t$	-4.83***	-6.07***	-4.20***	-5.34***	-3.73***	-4.52***
	$\hat{\gamma}$ significance	***	***	***	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

cont. Neighboring country rice to local rice price transmission levels model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Yaoundé, Cameroon	$\hat{\alpha}$	45.38***	58.03***	33.71***	54.25***	42.51***	48.66***
		(6.85)	(6.07)	(5.35)	(7.69)	(8.16)	(7.27)
	$\hat{\beta}$	0.75***	0.58***	0.73***	0.60***	0.50***	0.56***
		(12.26)	(6.59)	(12.60)	(9.16)	(10.55)	(9.10)
	$Adj.R^2$	0.68	0.37	0.69	0.54	0.65	0.54
	$ADF\ \hat{u}_t$	-3.33***	-5.08***	-2.40**	-5.09***	-3.13***	-3.62***
	PP $\hat{u}_t$	-5.92***	-6.43***	-4.74***	-5.12***	-3.25***	-4.86***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Garoua, Cameroon	$\hat{\alpha}$	32.66***	52.08***	27.28***	45.79***	28.44***	34.65***
		(4.17)	(4.52)	(3.23)	(5.39)	(5.44)	(4.79)
	$\hat{\beta}$	0.82***	0.60***	0.75***	0.64***	0.61***	0.66***
		(11.93)	(5.95)	(10.10)	(8.56)	(13.17)	(10.34)
	$Adj.R^2$	0.67	0.33	0.59	0.50	0.75	0.60
	$ADF\ \hat{u}_t$	-3.80***	-6.33***	-4.56***	-4.66***	-4.24***	-4.36***
	PP $\hat{u}_t$	-6.37***	-6.36***	-4.62***	-4.62***	-3.79***	-5.07***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Bamako, Mali	$\hat{\alpha}$	28.98***	53.23***	29.54***	50.69***	16.43***	27.03***
		(2.77)	(3.66)	(3.52)	(5.53)	(2.73)	(3.14)
	$\hat{\beta}$	1.15***	0.81***	1.01***	0.84***	0.96***	0.98***
		(9.59)	(4.85)	(10.49)	(7.96)	(13.82)	(9.87)
	$Adj.R^2$	0.61	0.28	0.65	0.51	0.80	0.62
	$ADF\ \hat{u}_t$	-5.29***	-5.80***	-4.87***	-3.88***	-3.85***	-5.65***
	PP $\hat{u}_t$	-5.30***	-5.84***	-4.90***	-5.68***	-3.98***	-5.73***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Mopti, Mali	$\hat{\alpha}$	23.46*	37.24*	17.16	67.19***	17.38**	36.15***
		(1.80)	(1.92)	(1.60)	(5.82)	(11.75)	(3.12)
	$\hat{\beta}$	1.21***	0.98***	1.15***	0.68***	0.95***	0.89***
		(8.51)	(4.62)	(9.80)	(5.36)	(11.75)	(7.01)
	$Adj.R^2$	0.60	0.30	0.67	0.37	0.80	0.51
	$ADF\ \hat{u}_t$	-3.76***	-4.24***	-3.81***	-4.88***	-2.38**	-4.29***
	PP $\hat{u}_t$	-3.90***	-4.26***	-3.88***	-4.95***	-2.58**	-4.23***
	$\hat{\gamma}$ significance	***	***	***	***		***

Note: a description of table contents is included below the first section of table 3D-1.

Table 3D-9: Neighboring country sorghum price transmission levels model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Malanville, Benin	$\hat{\alpha}$	24.92***	17.56***	17.08***	12.27***	11.21***	20.03***
		(6.21)	(3.52)	(4.26)	(4.25)	(5.52)	(9.56)
	$\hat{\beta}$	**1.25*** **	**1.54*** **	**1.26*** **	1.07***	0.75***	0.58***
		(12.24)	(12.14)	(12.32)	(14.55)	(13.48)	(11.36)
	$Adj. R^2$	0.60	0.60	0.60	0.68	0.67	0.60
	$ADF\ \hat{u}_t$	-1.21	-1.99**	-2.70***	0.35	-4.23***	-2.31**
	PP $\hat{u}_t$	-4.68***	-3.96***	-4.04***	-3.65***	-4.32***	-1.86*
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Accra, Ghana	$\hat{\alpha}$	16.11***	35.80***	25.61***	-15.43**	9.55**	11.09***
		(2.66)	(4.17)	(3.89)	(-2.47)	(2.33)	(3.95)
	$\hat{\beta}$	1.17***	0.98***	0.96***	**1.25*** **	0.54***	0.58***
		(12.77)	(7.53)	(9.59)	(13.21)	(8.64)	(13.52)
	$Adj. R^2$	0.73	0.49	0.61	0.75	0.61	0.76
	$ADF\ \hat{u}_t$	-1.51	-2.19**	-2.62***	-3.21***	-3.13***	-3.71***
	PP $\hat{u}_t$	-5.32***	-4.05***	-5.60***	-3.08***	-3.09***	-5.10***
	$\hat{\gamma}$ significance	***	***	***	**	***	***
Bolgatanga, Ghana	$\hat{\alpha}$	43.58***	47.98***	49.22***	5.84	15.97***	25.65***
		(6.33)	(7.08)	(7.29)	(0.98)	(5.25)	(7.49)
	$\hat{\beta}$	1.15***	1.22***	0.91***	**1.42*** **	0.71***	0.54***
		(7.23)	(7.80)	(5.85)	(10.32)	(9.66)	(6.81)
	$Adj. R^2$	0.47	0.50	0.36	0.64	0.66	0.43
	$ADF\ \hat{u}_t$	-2.12**	-2.71***	-2.64***	-1.86*	-4.41***	-2.04**
	PP $\hat{u}_t$	-3.59***	-4.65***	-4.21***	-3.12***	-3.83***	-3.40***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Lomé, Togo	$\hat{\alpha}$	31.89***	25.11***	21.58***	27.91***	25.05***	32.01***
		(6.70)	(4.63)	(4.59)	(6.10)	(8.22)	(9.79)
	$\hat{\beta}$	0.66***	0.81***	0.72***	0.41***	0.22***	0.17***
		(9.35)	(10.00)	(10.22)	(5.99)	(4.78)	(3.70)
	$Adj. R^2$	0.42	0.45	0.47	0.23	0.17	0.11
	$ADF\ \hat{u}_t$	-3.01***	-2.82***	-2.03**	-1.60	-3.33***	-2.06**
	PP $\hat{u}_t$	-3.82***	-3.96***	-4.33***	-2.42**	-3.11***	-2.71***
	$\hat{\gamma}$ significance	***	***	**	*	***	***
Korbongou, Togo	$\hat{\alpha}$	50.14***	48.90***	41.70***	32.95***	25.70***	33.63***
		(13.67)	(11.26)	(11.24)	(11.13)	(13.71)	(17.67)
	$\hat{\beta}$	0.73***	0.84***	0.78***	0.65***	0.43***	0.30***
		(7.40)	(7.17)	(7.75)	(8.08)	(8.09)	(6.00)
	$Adj. R^2$	0.31	0.30	0.33	0.35	0.38	0.25
	$ADF\ \hat{u}_t$	-2.41**	-1.71*	-2.81***	-3.26***	-4.15***	-3.03***
	PP $\hat{u}_t$	-5.28***	-5.31***	-4.94***	-5.31***	-6.32***	-4.42***
	$\hat{\gamma}$ significance	***	***	***	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

cont. Neighboring country sorghum price transmission levels model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Ouagadougou, Burkina Faso	$\hat{\alpha}$	25.36*** (3.43)	40.31*** (4.57)	29.25*** (4.28)	-2.47 (-0.30)	9.86** (2.60)	18.82*** (4.73)
	$\hat{\beta}$	**1.82***** (9.17)	**1.61***** (6.81)	**1.59***** (8.69)	**1.86***** (8.44)	0.94*** (9.30)	0.80*** (7.54)
	$Adj. R^2$	0.56	0.43	0.56	0.54	0.65	0.49
	$ADF\ \hat{u}_t$	-4.54***	-2.20**	-5.58***	-2.63***	-2.94***	-2.70***
	PP $\hat{u}_t$	-4.58***	-4.11***	-5.62***	-2.68***	-3.51***	-2.58**
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Dori, Burkina Faso	$\hat{\alpha}$	22.60*** (3.38)	39.03*** (4.61)	27.29*** (4.31)	-5.32 (-0.70)	8.88*** (2.72)	17.23*** (4.71)
	$\hat{\beta}$	**1.71***** (10.57)	**1.48***** (7.25)	**1.49***** (9.72)	**1.75***** (9.59)	0.87*** (11.13)	0.77*** (8.66)
	$Adj. R^2$	0.65	0.47	0.61	0.61	0.72	0.56
	$ADF\ \hat{u}_t$	-4.69***	-2.20**	-5.83***	-2.49**	-2.89***	-1.82*
	PP $\hat{u}_t$	-4.73***	-4.01***	-5.85***	-2.63***	-3.46***	-3.18***
	$\hat{\gamma}$ significance	***	***	***	**	***	***
Niamey, Niger	$\hat{\alpha}$	5.04 (1.29)	0.24 (0.05)	-1.76 (-0.41)	-2.87 (-0.87)	4.40** (2.12)	8.79*** (4.16)
	$\hat{\beta}$	**1.43***** (18.37)	**1.58***** (14.97)	**1.42***** (16.51)	**1.18***** (17.77)	0.73*** (17.31)	0.69*** (17.08)
	$Adj. R^2$	0.74	0.65	0.70	0.73	0.74	0.73
	$ADF\ \hat{u}_t$	-2.24**	-4.12***	-2.90***	-4.26***	-2.82***	-3.25***
	PP $\hat{u}_t$	-5.83***	-3.91***	-4.30***	-4.11***	-4.91***	-4.59***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Maradi, Niger	$\hat{\alpha}$	22.80*** (4.76)	16.94*** (2.97)	14.59*** (2.96)	8.06** (2.19)	8.48*** (4.22)	17.60*** (8.29)
	$\hat{\beta}$	**1.47***** (11.37)	**1.70***** (11.09)	**1.50***** (11.29)	**1.31***** (13.25)	0.87*** (16.04)	0.72*** (13.00)
	$Adj. R^2$	0.53	0.51	0.52	0.60	0.71	0.62
	$ADF\ \hat{u}_t$	-1.25	-2.50**	-2.83***	-3.81***	-3.63***	-4.32***
	PP $\hat{u}_t$	-4.02***	-3.36***	-3.36***	-3.78***	-5.37***	-4.32***
	$\hat{\gamma}$ significance	***	***	***	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

cont. Neighboring country sorghum price transmission levels model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
N'Djamena, Chad	$\hat{\alpha}$	39.88*** (8.32)	36.66*** (6.01)	25.41*** (5.24)	11.48*** (2.70)	12.24*** (5.20)	19.49*** (8.02)
	$\hat{\beta}$	1.00*** (9.63)	1.16*** (8.78)	1.16*** (11.05)	1.09*** (11.87)	0.69*** (13.52)	0.59*** (11.23)
	$Adj. R^2$	0.52	0.47	0.58	0.62	0.71	0.59
	$ADF\ \hat{u}_t$	-4.25***	-2.26**	-1.18	-3.10***	-3.89***	-2.99***
	PP $\hat{u}_t$	-4.24***	-3.51***	-3.59***	-3.13***	-3.86***	-2.96***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Moundou, Chad	$\hat{\alpha}$	48.80*** (10.31)	52.65*** (8.22)	37.39*** (7.35)	22.40*** (4.96)	21.12*** (7.28)	26.27*** (9.98)
	$\hat{\beta}$	0.93*** (7.88)	0.93*** (5.81)	1.04*** (8.15)	0.99*** (8.75)	0.58*** (7.84)	0.51*** (7.75)
	$Adj. R^2$	0.42	0.28	0.43	0.47	0.45	0.41
	$ADF\ \hat{u}_t$	0.19	-3.09***	-2.04**	-2.73***	-3.63***	-2.51**
	PP $\hat{u}_t$	-3.66***	-2.79***	-2.93***	-2.74***	-3.48***	-2.57**
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Bamako, Mali	$\hat{\alpha}$	33.20*** (4.38)	41.78*** (5.17)	34.19*** (5.11)	6.63 (0.78)	9.81*** (2.89)	20.77*** (5.48)
	$\hat{\beta}$	**1.58***** (7.92)	**1.55***** (7.27)	**1.44***** (8.16)	**1.59***** (7.12)	0.91*** (10.41)	0.74*** (7.42)
	$Adj. R^2$	0.51	0.47	0.53	0.46	0.70	0.48
	$ADF\ \hat{u}_t$	-3.52***	-3.11***	-2.39***	-2.87***	-1.17	-3.33***
	PP $\hat{u}_t$	-3.57***	-4.04***	-4.80***	-2.41**	-3.60***	-3.23***
	$\hat{\gamma}$ significance	***	***	***	**	***	***
Mopti, Mali	$\hat{\alpha}$	17.04*** (2.63)	9.34 (1.10)	3.76 (0.53)	-10.21* (-1.78)	-1.24 (-0.37)	5.93** (2.02)
	$\hat{\beta}$	**1.64***** (10.12)	**1.91***** (9.02)	**1.78***** (10.10)	**1.72***** (12.07)	1.07*** (12.71)	0.98*** (13.35)
	$Adj. R^2$	0.52	0.46	0.52	0.61	0.66	0.65
	$ADF\ \hat{u}_t$	-3.68***	-3.17***	-1.98**	-2.86***	-2.60***	-3.22***
	PP $\hat{u}_t$	-3.56***	-2.83***	-3.15***	-3.34***	-4.19***	-3.91***
	$\hat{\gamma}$ significance	***	***	***	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

Table 3D-10: Neighboring country millet price transmission levels model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
Accra, Ghana	$\hat{\alpha}$	29.96*** (3.12)	52.23*** (4.41)	87.82*** (7.07)	-11.44 (-1.20)	4.70 (0.98)	-8.94 (-1.00)
	$\hat{\beta}$	0.69*** (5.90)	0.49*** (3.35)	0.15 (0.96)	0.97*** (8.35)	0.50*** (8.60)	0.76*** (6.98)
	$Adj.R^2$	0.42	0.18	0.00	0.59	0.61	0.50
	$ADF\ \hat{u}_t$	-3.96***	-5.33***	-2.99***	-3.39***	-4.02***	-3.22***
	PP $\hat{u}_t$	-5.00***	-3.19***	-2.91***	-3.36***	-4.28***	-2.65***
	$\hat{\gamma}$ significance	***	***	***	***	***	**
Bolgatanga, Ghana	$\hat{\alpha}$	40.49*** (5.26)	73.83*** (7.12)	69.60*** (7.67)	7.37 (0.89)	14.05*** (3.42)	3.03 (0.42)
	$\hat{\beta}$	0.88*** (6.03)	0.34* (1.73)	0.58*** (3.40)	1.15*** (7.35)	0.60*** (7.76)	0.96*** (7.04)
	$Adj.R^2$	0.43	0.04	0.18	0.53	0.56	0.51
	$ADF\ \hat{u}_t$	-4.62***	-3.49***	-3.49***	-0.60	-3.70***	-2.65***
	PP $\hat{u}_t$	-4.68***	-2.55**	-3.38***	-3.24***	-3.58***	-2.54**
	$\hat{\gamma}$ significance	***	***	***		***	***
Ouagadougou, Burkina Faso	$\hat{\alpha}$	38.37*** (5.59)	69.65*** (7.12)	74.44*** (8.26)	1.14 (0.18)	9.89*** (3.57)	0.58 (0.09)
	$\hat{\beta}$	1.16*** (7.09)	0.53** (2.27)	0.62*** (2.87)	**1.60***** (10.68)	0.86*** (13.05)	1.26*** (8.61)
	$Adj.R^2$	0.51	0.08	0.13	0.71	0.78	0.61
	$ADF\ \hat{u}_t$	-5.02***	-4.64***	-2.93***	-2.18**	-3.60***	-2.85***
	PP $\hat{u}_t$	-5.01***	-2.66***	-2.83***	-3.62***	-4.48***	-2.77***
	$\hat{\gamma}$ significance	***	***	***	***	***	
Dori, Burkina Faso	$\hat{\alpha}$	36.71*** (5.64)	71.88*** (7.31)	78.28*** (8.52)	3.25 (0.49)	11.93*** (3.65)	-0.58 (-0.10)
	$\hat{\beta}$	1.09*** (7.75)	0.43** (2.03)	0.47** (2.39)	**1.40***** (9.77)	0.76*** (11.93)	1.17*** (9.30)
	$Adj.R^2$	0.56	0.06	0.09	0.67	0.75	0.65
	$ADF\ \hat{u}_t$	-4.98***	-3.97***	-2.99***	-1.89*	-3.80***	-2.96***
	PP $\hat{u}_t$	-4.97***	-2.54**	-2.89***	-3.22***	-4.24***	-2.93***
	$\hat{\gamma}$ significance	***	**	***	**	***	*
Niamey, Niger	$\hat{\alpha}$	13.06*** (3.49)	18.49*** (3.49)	10.91* (1.80)	5.23* (1.71)	6.79*** (3.29)	-4.51 (-1.62)
	$\hat{\beta}$	**1.15***** (15.18)	1.08*** (10.08)	**1.29***** (10.49)	1.04*** (16.77)	0.69*** (16.55)	0.97*** (17.97)
	$Adj.R^2$	0.68	0.48	0.50	0.72	0.72	0.77
	$ADF\ \hat{u}_t$	-5.46***	-2.57**	-0.29	-4.22***	-4.40***	-4.41***
	PP $\hat{u}_t$	-5.44***	-2.49**	-1.55	-4.37***	-4.50***	-4.41***
	$\hat{\gamma}$ significance	***	***	**	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

cont. Neighboring country millet price transmission levels model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
Maradi, Niger	$\hat{\alpha}$	21.05*** (4.52)	25.82*** (4.50)	22.70*** (3.31)	11.02*** (3.01)	8.39*** (3.89)	1.45 (0.43)
	$\hat{\beta}$	**1.29***** (10.72)	1.22*** (7.97)	**1.37***** (7.47)	**1.20***** (12.34)	0.87*** (15.12)	1.13*** (12.96)
	$Adj. R^2$	0.52	0.37	0.34	0.59	0.68	0.64
	$ADF\ \hat{u}_t$	-1.47	-0.94	-0.57	-1.46	-4.77***	-2.94***
	PP $\hat{u}_t$	-4.59***	-2.42**	-1.42	-3.83***	-4.86***	-3.92***
	$\hat{\gamma}$ significance	***	***	*	***	***	***
N'Djamena, Chad	$\hat{\alpha}$	33.52*** (6.86)	49.71*** (6.23)	43.88*** (5.29)	9.32* (1.91)	10.96*** (3.65)	1.57 (0.48)
	$\hat{\beta}$	0.80*** (9.31)	0.55*** (3.90)	0.74*** (5.08)	0.93*** (10.80)	0.60*** (11.32)	0.85*** (14.54)
	$Adj. R^2$	0.54	0.16	0.25	0.61	0.63	0.74
	$ADF\ \hat{u}_t$	-4.41***	-2.11**	-0.63	-2.49**	-3.95***	-4.30***
	PP $\hat{u}_t$	-4.35***	-1.98**	-1.15	-2.62***	-3.95***	-3.61***
	$\hat{\gamma}$ significance	***	***	*	***	***	***
Moundou, Chad	$\hat{\alpha}$	42.30*** (9.79)	57.34*** (8.31)	55.63*** (7.56)	19.55*** (4.46)	15.56*** (6.53)	8.35*** (3.26)
	$\hat{\beta}$	0.75*** (8.58)	0.48*** (3.42)	0.62*** (4.14)	0.87*** (9.76)	0.60*** (12.50)	0.84*** (16.23)
	$Adj. R^2$	0.50	0.13	0.18	0.56	0.68	0.78
	$ADF\ \hat{u}_t$	-4.56***	-2.00**	-0.77	-2.45**	-3.89***	-4.13***
	PP $\hat{u}_t$	-4.52***	-1.94*	-1.28	-2.46**	-4.02***	-3.98***
	$\hat{\gamma}$ significance	***	**	*	***	***	***
Bamako, Mali	$\hat{\alpha}$	54.83*** (6.92)	79.34*** (8.12)	84.61*** (7.24)	20.17** (2.58)	12.29*** (3.12)	11.85* (1.89)
	$\hat{\beta}$	0.67*** (3.62)	0.20 (0.85)	0.18 (0.66)	1.10*** (5.98)	0.85*** (9.13)	0.98*** (6.61)
	$Adj. R^2$	0.17	0.00	0.00	0.37	0.58	0.42
	$ADF\ \hat{u}_t$	-2.08**	-2.71***	-2.80***	-3.01***	-4.26***	-3.55***
	PP $\hat{u}_t$	-3.74***	-2.67***	-2.71***	-2.98***	-4.59***	-3.38***
	$\hat{\gamma}$ significance	***	**	**	***	***	***
Mopti, Mali	$\hat{\alpha}$	20.86*** (3.42)	28.26*** (3.22)	28.81*** (2.85)	-6.32 (-1.19)	0.69 (0.21)	-9.70** (-2.30)
	$\hat{\beta}$	**1.30***** (9.01)	1.16*** (5.62)	1.25*** (5.23)	**1.54***** (12.30)	0.99*** (12.52)	**1.33***** (13.39)
	$Adj. R^2$	0.49	0.27	0.24	0.65	0.66	0.68
	$ADF\ \hat{u}_t$	-4.42***	-1.94*	-0.39	-2.42**	-3.59***	-3.46***
	PP $\hat{u}_t$	-4.28***	-1.90*	-0.95	-2.95***	-3.45***	-3.52***
	$\hat{\gamma}$ significance	***	**		***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

Table 3D-11: Neighboring country cassava price transmission levels model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
Cotonou, Benin	$\hat{\alpha}$	34.97*** (10.81)	48.17*** (14.34)	47.60*** (12.72)	30.80*** (9.73)	25.71*** (8.15)	60.06*** (17.18)
	$\hat{\beta}$	0.57*** (11.54)	0.51*** (10.08)	0.41*** (7.27)	0.61*** (12.67)	0.65*** (13.57)	0.35*** (6.86)
	$Adj. R^2$	0.53	0.46	0.30	0.57	0.61	0.30
	$ADF\ \hat{u}_t$	-4.03***	-2.46**	-2.69***	-2.15**	-1.64*	-3.04***
	PP $\hat{u}_t$	-3.95***	-6.77***	-3.90***	-3.13***	-3.27***	-3.59***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Malanville, Benin	$\hat{\alpha}$	26.86*** (7.31)	41.07*** (10.43)	38.85*** (9.65)	18.64*** (6.48)	12.72*** (4.65)	51.78*** (14.40)
	$\hat{\beta}$	0.87*** (11.65)	0.78*** (9.97)	0.70*** (8.64)	1.02*** (17.48)	1.10*** (19.96)	0.63*** (9.00)
	$Adj. R^2$	0.57	0.49	0.42	0.75	0.80	0.47
	$ADF\ \hat{u}_t$	-4.21***	-2.62***	-1.27	-1.03	-5.59***	-3.00***
	PP $\hat{u}_t$	-4.08***	-6.58***	-4.18***	-4.23***	-5.50***	-4.63***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Accra, Ghana	$\hat{\alpha}$	53.99*** (5.79)	78.60*** (8.75)	32.14*** (2.67)	21.05*** (2.66)	16.28 (1.57)	65.06*** (7.25)
	$\hat{\beta}$	1.22*** (3.19)	0.61 (1.65)	**2.09***** (4.23)	**2.52***** (7.75)	**2.61***** (6.10)	1.04*** (2.81)
	$Adj. R^2$	0.14	0.03	0.23	0.50	0.38	0.11
	$ADF\ \hat{u}_t$	-3.30***	-5.94***	-1.02	-3.23***	-2.63***	-3.49***
	PP $\hat{u}_t$	-3.31***	-6.03***	-3.35***	-3.24***	-2.66***	-3.63***
	$\hat{\gamma}$ significance	***	***	***	***	**	**
Lomé, Togo	$\hat{\alpha}$	39.18*** (14.84)	54.42*** (18.04)	46.91*** (16.49)	34.02*** (14.41)	27.66*** (13.69)	60.48*** (24.85)
	$\hat{\beta}$	0.59*** (12.83)	0.48*** (9.27)	0.50*** (10.16)	0.65*** (16.02)	0.73*** (20.82)	0.41*** (10.09)
	$Adj. R^2$	0.58	0.42	0.46	0.68	0.78	0.49
	$ADF\ \hat{u}_t$	-2.10**	-2.45**	-5.74***	-5.17***	-5. 85***	-4.09***
	PP $\hat{u}_t$	-5.38***	-6.74***	-5.86***	-5.13***	-6.35***	-5.40***
	$\hat{\gamma}$ significance	***	***	***	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

cont. Neighboring country cassava price transmission levels model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Korbongou, Togo	$\hat{\alpha}$	24.00***	36.40***	41.96***	26.27***	21.56***	54.93***
		(6.25)	(9.47)	(8.92)	(5.87)	(4.69)	(12.48)
	$\hat{\beta}$	0.93***	0.88***	0.63***	0.85***	0.89***	0.54***
		(12.44)	(11.77)	(6.87)	(9.75)	(9.97)	(6.52)
	$Adj.R^2$	0.56	0.54	0.28	0.44	0.45	0.28
	$ADF\ \hat{u}_t$	-3.34***	-4.41***	-2.60***	-1.81*	-2.36**	-2.85***
	PP $\hat{u}_t$	-4.97***	-7.83***	-4.08***	-3.39***	-3.00***	-3.94***
	$\hat{\gamma}$ significance	***	***	***	***	**	***
Yaoundé, Cameroon	$\hat{\alpha}$	53.27***	76.55***	28.57***	30.39***	20.70**	68.17***
		(6.12)	(8.48)	(2.56)	(3.41)	(2.02)	(7.75)
	$\hat{\beta}$	1.04***	0.55*	**1.87*** **	**1.79*** **	**2.03*** **	0.74**
		(3.33)	(1.68)	(4.68)	(5.61)	(5.54)	(2.35)
	$Adj.R^2$	0.12	0.03	0.23	0.30	0.30	0.06
	$ADF\ \hat{u}_t$	-3.58***	-6.38***	-3.41***	-2.77***	-2.15**	-1.87*
	PP $\hat{u}_t$	-3.57***	-6.40***	-3.29***	-2.69***	-2.06**	-3.19***
	$\hat{\gamma}$ significance	***	***	***	**	**	***

Note: a description of table contents is included below the first section of table 3D-1.

Table 3D-12: Neighboring country yams price transmission levels model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Accra, Ghana	$\hat{\alpha}$	64.22***	58.47***	65.09***	32.02***	57.06***	51.05***
		(8.06)	(9.56)	(7.27)	(4.17)	(6.37)	(6.94)
	$\hat{\beta}$	0.54***	0.44***	0.61***	0.85***	0.57***	0.53***
		(3.57)	(3.74)	(3.55)	(5.83)	(3.37)	(3.75)
	$Adj. R^2$	0.17	0.18	0.16	0.36	0.18	0.18
	$ADF\ \hat{u}_t$	-1.77*	-2.58**	-3.09***	-0.60	0.80	-3.45***
	PP $\hat{u}_t$	-5.24***	-4.33***	-2.96***	-2.90***	-4.70***	-3.41***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Bolgatanga, Ghana	$\hat{\alpha}$	69.67***	63.26***	56.92***	29.63***	61.02***	52.36***
		(8.37)	(9.44)	(6.57)	(3.80)	(7.05)	(6.66)
	$\hat{\beta}$	0.47***	0.36***	0.78***	0.93***	0.54***	0.51***
		(2.91)	(2.76)	(4.66)	(6.19)	(3.22)	(3.36)
	$Adj. R^2$	0.12	0.11	0.27	0.40	0.18	0.15
	$ADF\ \hat{u}_t$	-1.62*	-1.76*	-1.09	-2.36**	-0.37	-2.57**
	PP $\hat{u}_t$	-5.23***	-3.93***	-2.44**	-2.15**	-4.18***	-2.50**
	$\hat{\gamma}$ significance	***	***	***	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

Table 3D-13: Neighboring country cowpeas price transmission levels model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Garoua, Cameroon	$\hat{\alpha}$	60.24***	51.59***	46.26**	59.22***	49.96**	37.04**
		(3.90)	(4.16)	(2.55)	(3.59)	(2.52)	(2.21)
	$\hat{\beta}$	0.46***	0.56***	0.61***	0.43***	0.43***	0.41***
		(4.77)	(7.29)	(5.42)	(4.19)	(3.50)	(3.96)
	$Adj.R^2$	0.23	0.42	0.29	0.19	0.14	0.17
	$ADF\ \hat{u}_t$	-1.91*	-1.83*	-1.58	-2.43**	-1.73*	-1.39
	PP $\hat{u}_t$	-1.89*	-4.35***	-3.46***	-1.65*	-2.16**	-1.74*
	$\hat{\gamma}$ significance		***	**		**	**
Cotonou, Benin	$\hat{\alpha}$	74.67***	93.99***	78.41***	51.10***	49.02***	31.67***
		(8.72)	(11.97)	(8.21)	(5.33)	(3.75)	(10.65)
	$\hat{\beta}$	0.54***	0.45***	0.62***	0.66***	0.62***	0.63***
		(8.78)	(7.95)	(9.02)	(9.54)	(6.64)	(10.65)
	$Adj.R^2$	0.62	0.57	0.63	0.66	0.48	0.71
	$ADF\ \hat{u}_t$	-3.73***	-5.09***	-3.61***	-2.15**	-3.50***	-4.20***
	PP $\hat{u}_t$	-3.81***	-5.00***	-2.82***	-2.88***	-3.49***	-4.16***
	$\hat{\gamma}$ significance	***	***	*	**	***	***
Niamey, Niger	$\hat{\alpha}$	39.46***	46.26***	41.52***	37.54***	19.17***	14.91***
		(6.54)	(6.59)	(5.74)	(5.81)	(2.92)	(2.81)
	$\hat{\beta}$	1.02***	0.99***	1.11***	1.01***	1.10***	1.00***
		(12.93)	(10.78)	(11.69)	(12.43)	(12.83)	(14.34)
	$Adj.R^2$	0.62	0.53	0.57	0.63	0.61	0.67
	$ADF\ \hat{u}_t$	-2.35**	-3.97***	-1.38	-3.21***	-3.52***	-3.07**
	PP $\hat{u}_t$	-2.95***	-3.96***	-3.82***	-2.64***	-3.69***	-3.12***
	$\hat{\gamma}$ significance	***	***	***	***	***	***
Maradi, Niger	$\hat{\alpha}$	61.94***	72.70***	66.56***	59.41***	40.51***	32.80***
		(9.94)	(9.88)	(8.83)	(8.95)	(5.75)	(6.02)
	$\hat{\beta}$	1.01***	0.92***	1.10***	1.01***	1.13***	1.05***
		(10.28)	(7.89)	(9.22)	(9.98)	(10.16)	(12.17)
	$Adj.R^2$	0.55	0.42	0.50	0.56	0.55	0.63
	$ADF\ \hat{u}_t$	-0.53	-0.82	0.17	-2.33**	-3.65***	-3.20***
	PP $\hat{u}_t$	-2.95***	-3.37***	-3.04***	-2.36**	-3.74***	-3.23***
	$\hat{\gamma}$ significance	***	***	***	**	***	***

Note: a description of table contents is included below the first section of table 3D-1.

Table 3D-14: Commercial hub-to-urban market maize, millet, and sorghum price transmission levels model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
Maize							
Hub: Kano	$\hat{\alpha}$	7.08 (1.50)	18.66*** (3.33)	9.11 (1.54)	0.11 (0.03)	…	5.01* (1.79)
	$\hat{\beta}$	**1.35***** (11.81)	**1.31***** (9.67)	**1.40***** (9.77)	**1.24***** (15.44)	…	0.94*** (14.33)
	$Adj. R^2$	0.56	0.46	0.47	0.69	…	0.68
	$ADF\ \hat{u}_t$	-2.03**	-2.18**	-1.69*	-3.53***	…	-6.28***
	PP $\hat{u}_t$	-3.97***	-5.38***	-3.34***	-4.70***	…	-6.16***
	$\hat{\gamma}$ significance	***	***	***	***	…	***
Millet							
Hub: Kano	$\hat{\alpha}$	21.73*** (4.31)	23.89*** (3.96)	19.61*** (2.75)	5.83* (1.70)	…	-1.55 (-0.51)
	$\hat{\beta}$	1.15*** (9.43)	1.15*** (7.88)	1.31*** (7.60)	**1.22***** (14.69)	…	1.10*** (15.43)
	$Adj. R^2$	0.45	0.36	0.35	0.67	…	0.71
	$ADF\ \hat{u}_t$	-4.11***	-2.80***	-1.37	-2.66***	…	-3.10***
	PP $\hat{u}_t$	-3.97***	-2.70***	-1.87*	-3.72***	…	-3.35***
	$\hat{\gamma}$ significance	***	***		***	…	***
Sorghum							
Hub: Kano	$\hat{\alpha}$	20.26*** (3.66)	12.54** (2.06)	10.09* (1.83)	1.10 (0.35)	…	12.02*** (6.29)
	$\hat{\beta}$	**1.32***** (9.73)	**1.55***** (10.35)	**1.41***** (10.34)	**1.29***** (16.92)	…	0.77*** (16.90)
	$Adj. R^2$	0.47	0.50	0.50	0.73	…	0.75
	$ADF\ \hat{u}_t$	-1.78*	-1.54	-1.74*	-1.66*	…	-2.43**
	PP $\hat{u}_t$	-3.98***	-2.98***	-3.47***	-2.14**	…	-5.74***
	$\hat{\gamma}$ significance	***	***	***	***	…	***
Cowpea							
Hub: Kano	$\hat{\alpha}$	25.30*** (7.97)	32.57*** (6.06)	27.10*** (4.90)	23.86*** (6.77)	…	8.42*** (2.62)
	$\hat{\beta}$	0.87*** (28.96)	0.84*** (16.34)	0.93*** (17.67)	0.85*** (26.34)	…	0.79*** (26.67)
	$Adj. R^2$	0.88	0.69	0.72	0.87	…	0.87
	$ADF\ \hat{u}_t$	-2.13**	-1.59	-5.33***	-3.25***	…	-2.31**
	PP $\hat{u}_t$	-7.04***	-5.25***	-5.38***	-6.40***	…	-7.82***
	$\hat{\gamma}$ significance	***	***	***	***	…	***

Note: a description of table contents is included below the first section of table 3D-1.

Table 3D-15: Commercial hub-to-urban cassava and yams price transmission levels model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
			Cassava				
Hub 1: Lagos	$\hat{\alpha}$	…	26.59*** (6.63)	22.55*** (5.45)	8.47** (2.21)	4.30 (1.06)	38.19*** (11.87)
	$\hat{\beta}$	…	0.76*** (13.68)	0.72*** (12.60)	0.85*** (16.10)	0.88*** (15.54)	0.63*** (14.29)
	$Adj.R^2$	…	0.61	0.57	0.68	0.67	0.66
	$ADF\ \hat{u}_t$	…	-3.79***	-4.33***	-2.34**	-2.50**	-6.36***
	PP $\hat{u}_t$	…	-8.00***	-6.68***	-6.03***	-5.61***	-6.38***
	$\hat{\gamma}$ significance	…	***	***	***	***	***
Hub 2: Kano	$\hat{\alpha}$	19.42*** (5.74)	39.51*** (9.32)	27.78*** (7.78)	10.54*** (4.22)	…	45.75*** (15.00)
	$\hat{\beta}$	0.77*** (15.54)	0.61*** (9.89)	0.69*** (13.22)	0.88*** (24.07)	…	0.55*** (12.66)
	$Adj.R^2$	0.67	0.45	0.59	0.83	…	0.60
	$ADF\ \hat{u}_t$	-3.93***	-2.16**	-6.34***	-5.43***	…	-4.84***
	PP $\hat{u}_t$	-6.16***	-6.88***	-6.42***	-6.48***	…	-6.49***
	$\hat{\gamma}$ significance	***	***	***	*	…	***
			Yams				
Hub 1: FCT (Abuja)	$\hat{\alpha}$	14.14*** (2.79)	34.58*** (9.48)	15.51*** (3.21)	…	24.71*** (4.57)	24.37*** (6.25)
	$\hat{\beta}$	0.90*** (11.64)	0.57*** (10.23)	0.96*** (12.95)	…	0.67*** (8.06)	0.67*** (11.49)
	$Adj.R^2$	0.53	0.47	0.58	…	0.37	0.55
	$ADF\ \hat{u}_t$	-1.84*	-6.81***	-1.66*	…	-1.34	-7.49***
	PP $\hat{u}_t$	-6.16***	-6.70***	-5.31***	…	-5.35***	-7.69***
	$\hat{\gamma}$ significance	***	***	***	…	***	***
Hub 2: Kano	$\hat{\alpha}$	9.50** (2.07)	37.28*** (9.30)	25.84*** (4.54)	23.28*** (4.73)	…	32.74*** (5.98)
	$\hat{\beta}$	0.90*** (13.75)	0.49*** (8.50)	0.70*** (8.59)	0.56*** (8.06)	…	0.48*** (6.45)
	$Adj.R^2$	0.64	0.40	0.40	0.37	…	0.30
	$ADF\ \hat{u}_t$	-0.67	-3.88***	-2.02**	-1.78*	…	-4.78***
	PP $\hat{u}_t$	-6.71***	-7.09***	-4.88***	-4.52***	…	-4.68***
	$\hat{\gamma}$ significance	***	***	***	***	…	***

Note: a description of table contents is included below the first section of table 3D-1.

Table 3D-16: Commercial hub-to-urban local rice price transmission levels model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Hub 1: Kano	$\hat{\alpha}$	-13.46*** (-3.43)	9.62* (1.75)	-0.62 (-0.18)	5.37 (1.42)	…	6.60* (1.76)
	$\hat{\beta}$	**1.40***** (29.11)	**1.14***** (17.00)	**1.12***** (26.36)	**1.14***** (24.66)	…	1.05*** (23.80)
	$Adj. R^2$	0.89	0.73	0.87	0.85	…	0.86
	$ADF\ \hat{u}_t$	-5.25***	-7.17***	-6.10***	-3.17***	…	-4.23***
	PP $\hat{u}_t$	-5.40***	-7.23***	-6.06***	-5.66***	…	-6.00***
	$\hat{\gamma}$ significance	***	***	***	***	…	***
Hub 2: FCT	$\hat{\alpha}$	-1.46 (-0.27)	16.15*** (3.00)	2.52 (0.66)	…	7.54** (2.51)	15.09*** (3.38)
	$\hat{\beta}$	1.04*** (19.81)	0.87*** (16.54)	0.91*** (24.19)	…	0.75*** (24.66)	0.78*** (18.36)
	$Adj. R^2$	0.77	0.70	0.83	…	0.85	0.76
	$ADF\ \hat{u}_t$	-4.58***	-8.27***	-2.54**	…	-3.14***	-3.04***
	PP $\hat{u}_t$	-6.17***	-8.39***	-7.73***	…	-5.30***	-7.68***
	$\hat{\gamma}$ significance	***	***	***	…	***	***
Hub 3: Enugu	$\hat{\alpha}$	2.37 (0.51)	21.55*** (4.22)	…	13.96*** (3.85)	10.79*** (4.01)	19.87*** (4.46)
	$\hat{\beta}$	1.07*** (22.32)	0.87*** (16.42)	…	0.91*** (24.19)	0.77*** (26.36)	0.78*** (17.36)
	$Adj. R^2$	0.81	0.69	…	0.83	0.87	0.74
	$ADF\ \hat{u}_t$	-5.49***	-7.74***	…	-2.65***	-5.98***	-6.15***
	PP $\hat{u}_t$	-6.65***	-7.88***	…	-8.14***	-5.98***	-6.24***
	$\hat{\gamma}$ significance	***	***	…	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

Table 3D-17: Commercial hub-to-urban imported rice price transmission levels model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
Hub 1: Lagos	$\hat{\alpha}$	…	7.21 (1.26)	-8.00* (-1.77)	3.06 (0.92)	-2.71 (-0.75)	10.97** (2.39)
	$\hat{\beta}$	…	**1.09***** (22.99)	**1.14***** (30.31)	**1.05***** (37.99)	1.05*** (34.11)	1.00*** (27.20)
	$Adj.R^2$	…	0.82	0.89	0.92	0.92	0.87
	$ADF\ \hat{u}_t$	…	-5.47***	-7.52***	-2.04**	-1.42	-3.28***
	PP $\hat{u}_t$	…	-5.47***	-7.52***	-8.91***	-8.11***	-6.77***
	$\hat{\gamma}$ significance	…	***	***	***	***	***
Hub 2: Rivers	$\hat{\alpha}$	15.55*** (3.41)	…	1.04 (0.20)	13.08*** (2.89)	9.15** (1.99)	20.74*** (4.26)
	$\hat{\beta}$	0.75*** (22.99)	…	0.92*** (24.83)	0.84*** (25.87)	0.81*** (24.03)	0.79*** (23.75)
	$Adj.R^2$	0.82	…	0.84	0.85	0.84	0.84
	$ADF\ \hat{u}_t$	-5.60***	…	-5.22***	-2.08**	-3.08***	-1.92*
	PP $\hat{u}_t$	-5.58***	…	-5.22***	-5.41***	-3.70***	-6.10***
	$\hat{\gamma}$ significance	***	…	***	***	***	***
Hub 3: Enugu	$\hat{\alpha}$	19.31*** (5.75)	20.31*** (4.22)	…	17.80*** (5.53)	11.31*** (3.66)	23.96*** (5.96)
	$\hat{\beta}$	0.78*** (30.31)	0.92*** (24.83)	…	0.87*** (35.08)	0.87*** (35.32)	0.83*** (28.02)
	$Adj.R^2$	0.89	0.84	…	0.91	0.92	0.88
	$ADF\ \hat{u}_t$	-7.59***	-5.15***	…	-4.41***	-1.95**	-5.97***
	PP $\hat{u}_t$	-7.57***	-5.17***	…	-2.78***	-6.37***	-6.05***
	$\hat{\gamma}$ significance	***	***	…	***	***	***
Hub 4: Kano	$\hat{\alpha}$	11.56*** (3.77)	10.38** (2.00)	-2.79 (-0.77)	7.68*** (2.65)	…	18.95*** (4.55)
	$\hat{\beta}$	0.87*** (34.11)	1.04*** (24.03)	**1.06***** (35.32)	0.98*** (40.87)	…	0.90*** (27.16)
	$Adj.R^2$	0.92	0.84	0.92	0.94	…	0.89
	$ADF\ \hat{u}_t$	-1.35	-2.67***	-2.16**	-7.20***	…	-6.58***
	PP $\hat{u}_t$	-8.32***	-3.78***	-6.43***	-7.39***	…	-6.79***
	$\hat{\gamma}$ significance	***	***	***	***	…	***

Note: a description of table contents is included below the first section of table 3D-1.

Table 3D-18: Commercial hub-to-urban imported rice to local rice price transmission levels model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Hub 1: Lagos	$\hat{\alpha}$	…	20.53*** (3.58)	5.01 (1.24)	10.31*** (2.65)	8.54*** (2.99)	12.95*** (2.94)
	$\hat{\beta}$	…	0.70*** (14.70)	0.75*** (22.38)	0.75*** (23.38)	0.63*** (25.58)	0.67*** (19.11)
	$Adj.R^2$	…	0.64	0.81	0.82	0.86	0.77
	$ADF\ \hat{u}_t$	…	-3.24***	-3.56***	-7.57***	-6.09***	-3.67***
	PP $\hat{u}_t$	…	-7.74***	-7.16***	-7.72***	-6.21***	-6.89***
	$\hat{\gamma}$ significance	…	***	***	***	***	***
Hub 2: Rivers	$\hat{\alpha}$	2.46 (0.52)	…	9.12** (2.31)	15.28*** (3.84)	14.73*** (4.77)	19.46*** (4.43)
	$\hat{\beta}$	0.73*** (21.75)	…	0.62*** (21.89)	0.62*** (21.66)	0.49*** (21.70)	0.54*** (17.70)
	$Adj.R^2$	0.80	…	0.80	0.80	0.81	0.74
	$ADF\ \hat{u}_t$	-3.44***	…	-4.17***	-6.73***	-3.35***	-3.34***
	PP $\hat{u}_t$	-5.03***	…	-6.33***	-6.94***	-4.78***	-5.76***
	$\hat{\gamma}$ significance	***	…	***	***	***	***
Hub 3: Enugu	$\hat{\alpha}$	6.47* (1.77)	27.00*** (5.70)	…	19.54*** (5.92)	16.79*** (6.81)	22.29*** (5.55)
	$\hat{\beta}$	0.76*** (27.10)	0.60*** (16.62)	…	0.63*** (24.96)	0.52*** (26.51)	0.55*** (18.73)
	$Adj.R^2$	0.86	0.70	…	0.84	0.87	0.77
	$ADF\ \hat{u}_t$	-5.32***	-5.73***	…	-7.75***	-5.23***	-5.61***
	PP $\hat{u}_t$	-6.62***	-7.72***	…	-7.88***	-5.18***	-5.64***
	$\hat{\gamma}$ significance	***	***	…	***	***	***
Hub 4: Kano	$\hat{\alpha}$	-4.27 (-1.46)	18.27*** (3.73)	7.94** (2.60)	14.26*** (4.23)	…	14.16*** (4.33)
	$\hat{\beta}$	0.88*** (36.20)	0.71*** (17.38)	0.70*** (27.50)	0.70*** (25.06)	…	0.65*** (25.08)
	$Adj.R^2$	0.92	0.74	0.88	0.85	…	0.87
	$ADF\ \hat{u}_t$	-5.04***	-7.47***	-6.41***	-6.02***	…	-1.92*
	PP $\hat{u}_t$	-8.12***	-7.52***	-6.47***	-6.17***	…	-6.77***
	$\hat{\gamma}$ significance	***	***	***	***	…	***

Note: a description of table contents is included below the first section of table 3D-1.

Table 3D-19: Urban-to-rural market maize, millet, sorghum, and cowpea price transmission levels model estimation results

	Lagos	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
			Maize			
$\hat{\alpha}$	7.58	6.42	18.01**	11.75***	-1.48	25.63***
	(0.78)	(0.52)	(2.03)	(3.17)	(-0.43)	(4.94)
$\hat{\beta}$	0.95***	0.91***	0.78***	0.63***	1.05***	0.51***
	(8.50)	(6.94)	(8.02)	(11.80)	(15.01)	(5.38)
$Adj. R^2$	0.60	0.50	0.57	0.75	0.87	0.37
$ADF\ \hat{u}_t$	-3.10***	-4.20***	-5.12***	-3.52***	-4.32***	-4.61***
PP $\hat{u}_t$	-2.62***	-4.15***	-5.22***	-3.11***	-4.24***	-4.51***
$\hat{\gamma}$ significance	*	***	***	***	***	***
			Millet			
$\hat{\alpha}$	28.93**	89.29***	71.92***	11.78	2.73	18.94***
	(2.29)	(8.78)	(4.34)	(1.67)	(0.71)	(5.23)
$\hat{\beta}$	0.55***	-0.14	0.10	0.65***	0.91***	0.44***
	(3.98)	(-1.35)	(0.65)	(6.98)	(11.52)	(7.19)
$Adj. R^2$	0.30	0.02	-0.02	0.58	0.79	0.59
$ADF\ \hat{u}_t$	-2.99***	-3.73***	-1.49	-1.50	-5.04***	-3.43***
PP $\hat{u}_t$	-2.67***	-2.21**	-1.36	-3.09***	-5.37***	-3.32****
$\hat{\gamma}$ significance	***	**	**	**	***	***
			Sorghum			
$\hat{\alpha}$	7.44	18.20	34.39***	9.74**	1.38	5.82
	(0.65)	(1.06)	(3.98)	(2.49)	(0.40)	(1.11)
$\hat{\beta}$	0.86***	0.70***	0.61***	0.70***	0.92***	0.86***
	(7.33)	(4.32)	(6.51)	(13.12)	(12.81)	(8.32)
$Adj. R^2$	0.53	0.27	0.47	0.78	0.82	0.59
$ADF\ \hat{u}_t$	-1.78*	-2.85***	-3.24***	-3.48***	-4.14***	-6.04***
PP $\hat{u}_t$	-3.21***	-2.80***	-8.62***	-3.48***	-4.00***	-6.00***
$\hat{\gamma}$ significance	***	**	***	***	***	***
			Cowpea			
$\hat{\alpha}$	-17.08	-6.92	34.74***	20.40**	45.63***	8.06
	(-0.98)	(-0.40)	(3.12)	(2.43)	(4.85)	(1.28)
$\hat{\beta}$	1.13***	1.00***	0.66***	0.78***	0.39***	0.91***
	(9.30)	(8.68)	(9.48)	(12.22)	(5.70)	(17.36)
$Adj. R^2$	0.71	0.66	0.72	0.81	0.40	0.86
$ADF\ \hat{u}_t$	-2.22**	-4.99***	-5.79***	-2.66***	-4.33***	-6.46***
PP $\hat{u}_t$	-2.10**	-4.99***	-5.77***	-2.62***	-4.42***	6.70***
$\hat{\gamma}$ significance		***	***		***	***

Note: a description of table contents is included below the first section of table 3D-1.

Table 3D-20: Urban-to- rural market cassava and yams price transmission levels model estimation results

	Lagos	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
			Cassava			
$\hat{\alpha}$	3.01 (0.36)	35.41** (2.46)	54.61*** (9.30)	-24.01** (-2.61)	7.76* (1.82)	38.04*** (4.37)
$\hat{\beta}$	0.92*** (9.45)	0.57*** (3.73)	0.31*** (4.66)	**1.22*** ** (11.53)	0.85*** (16.69)	0.53*** (5.66)
$Adj.R^2$	0.65	0.22	0.31	0.74	0.86	0.40
$ADF\ \hat{u}_t$	-3.66***	-0.62	-5.78***	-4.17***	-5.50***	-4.65***
PP $\hat{u}_t$	-3.93***	-3.56***	-5.86***	-4.21***	-5.61***	-4.67***
$\hat{\gamma}$ significance	***	***	***	**	***	***
			Yams			
$\hat{\alpha}$	40.67** (2.64)	80.96*** (12.37)	46.60*** (3.98)	26.87*** (3.31)	55.66*** (3.18)	32.86*** (2.89)
$\hat{\beta}$	0.60*** (3.85)	0.07 (0.94)	0.50*** (4.35)	0.49*** (4.97)	0.42** (2.29)	0.54*** (2.89)
$Adj.R^2$	0.23	-0.00	0.28	0.34	0.11	0.22
$ADF\ \hat{u}_t$	-4.11***	-4.76***	-3.22***	-5.69***	-0.77	-6.42***
PP $\hat{u}_t$	-4.07***	-4.87***	-3.03***	-3.80***	-3.31***	-4.78***
$\hat{\gamma}$ significance	***	***	***	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

Table 3D-21: Urban-to- rural market local rice, imported rice, and imported rice to local rice price transmission levels model estimation results

	Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Local Rice						
$\hat{\alpha}$	116.87***	37.28***	37.12***	58.38***	32.05***	19.18
	(12.80)	(3.16)	(4.77)	(4.06)	(4.95)	(1.59)
$\hat{\beta}$	0.09	0.65***	0.61***	0.48***	0.70***	0.78***
	(1.31)	(7.09)	(9.65)	(4.27)	(11.33)	(7.57)
$Adj.R^2$	0.02	0.51	0.66	0.27	0.78	0.54
$ADF\ \hat{u}_t$	-3.39***	-4.54***	-6.17***	-2.98***	-4.11***	-4.68***
PP $\hat{u}_t$	-3.48***	-4.68***	-6.13***	-2.84***	-4.16***	-4.60***
$\hat{\gamma}$ significance	***	***	***	**	***	***
Imported Rice						
$\hat{\alpha}$	21.69**	21.64**	57.83***	28.52**	43.29***	30.01**
	(2.12)	(2.17)	(4.08)	(2.07)	(3.61)	(2.13)
$\hat{\beta}$	0.87***	0.85***	0.65***	0.78***	0.73***	0.82***
	(13.03)	(14.93)	(7.75)	(9.37)	(9.57)	(9.59)
$Adj.R^2$	0.78	0.83	0.56	0.65	0.72	0.66
$ADF\ \hat{u}_t$	-6.51***	-4.71***	-1.72*	-3.09***	1.28	-5.68***
PP $\hat{u}_t$	-6.52***	-4.73***	-3.94***	-3.24***	-5.00***	-5.79***
$\hat{\gamma}$ significance	***	***	***	**	***	***
Imported Rice to Local Rice						
$\hat{\alpha}$	117.14***	42.03***	43.89***	36.25***	40.84***	18.52
	(10.16)	(2.94)	(5.59)	(3.40)	(5.49)	(1.50)
$\hat{\beta}$	0.08	0.45***	0.41***	0.51***	0.41***	0.56***
	(1.01)	(5.50)	(8.71)	(7.85)	(8.68)	(7.47)
$Adj.R^2$	0.00	0.38	0.61	0.56	0.68	0.54
$ADF\ \hat{u}_t$	-3.39***	-4.59***	-6.50***	-3.54***	-3.60***	-4.53***
PP $\hat{u}_t$	-3.48***	-4.61***	-6.50***	-3.49***	-3.56***	-4.51***
$\hat{\gamma}$ significance	***	***	***	***	***	***

Note: a description of table contents is included below the first section of table 3D-1.

Appendix 3E. Error Correction Mechanism (ECM) Model Results

Table 3E-1: World maize price transmission ECM model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
World Bank (US Gulf)	$\hat{\gamma}$	-0.19*** (-3.67)	-0.33*** (-4.64)	-0.15*** (-2.86)	-0.13*** (-3.02)	-0.18*** (-3.13)	-0.22*** (-3.72)
	$\hat{\delta}$	-0.74 (-1.58)	-0.10 (-0.14)	-0.56 (-1.05)	0.21 (0.53)	0.16 (0.32)	-0.30 (-0.66)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	34%	55%	27%	25%	32%	40%
	1 yr. % adj.	90%	99%	83%	79%	88%	94%
IMF (US Gulf)	$\hat{\gamma}$	-0.19*** (-3.68)	-0.33*** (-4.65)	-0.15*** (-2.84)	-0.13*** (-3.02)	-0.18*** (-3.14)	-0.22*** (-3.73)
	$\hat{\delta}$	-0.76 (-1.62)	-0.13 (-0.14)	-0.55 (-1.03)	0.20 (0.52)	0.05 (0.09)	-0.38 (-0.83)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	34%	54%	27%	25%	32%	40%
	1 yr. % adj.	90%	99%	82%	79%	88%	94%
GIEWS International (US Gulf)	$\hat{\gamma}$	-0.19*** (-3.65)	-0.33*** (-4.65)	-0.15*** (-2.87)	-0.13*** (-3.02)	-0.18*** (-3.14)	-0.22*** (-3.73)
	$\hat{\delta}$	-0.75 (-1.62)	-0.07 (-0.09)	-0.46 (-0.84)	0.19 (0.48)	-0.02 (-0.04)	-0.53 (-1.17)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	34%	55%	27%	25%	32%	40%
	1 yr. % adj.	90%	99%	83%	79%	88%	94%
GIEWS International (Argentina)	$\hat{\gamma}$	-0.19*** (-3.56)	-0.36*** (-4.94)	-0.16*** (-3.05)	-0.13*** (-2.83)	-0.18*** (-3.08)	-0.22*** (-3.63)
	$\hat{\delta}$	-0.57 (-1.19)	0.14 (0.20)	0.02 (0.03)	-0.08 (-0.21)	-0.27 (-0.55)	-0.57 (-1.24)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	34%	59%	31%	24%	32%	39%
	1 yr. % adj.	90%	99%	87%	78%	88%	93%
FAO (Argentina)	$\hat{\gamma}$	-0.19*** (-3.62)	-0.36*** (-4.94)	-0.17*** (-3.08)	-0.13*** (-2.90)	-0.18*** (-3.10)	-0.22*** (-3.66)
	$\hat{\delta}$	-0.47 (-0.98)	0.05 (0.07)	-0.06 (-0.11)	-0.14 (-0.34)	-0.29 (-0.58)	-0.34 (-0.73)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	35%	59%	31%	24%	32%	39%
	1 yr. % adj.	91%	99%	87%	78%	88%	94%

Note: t-statistics are in parentheses. ***, **, and * denote 1%, 5%, and 10% significance, respectively. A **bold** EPT parameter ($\hat{\beta}$) signifies that it is statistically significantly greater than 1 at the 5% significance level. A statistically significant estimated ECM term ($\hat{\gamma}$) implies cointegration (Banerjee et al. 1986).

cont. World maize price transmission ECM model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
FAO (US Gulf)	$\hat{\gamma}$	-0.19*** (-3.73)	-0.33*** (-4.67)	-0.15*** (-2.92)	-0.13*** (-3.06)	-0.18*** (-3.13)	-0.23*** (-3.76)
	$\hat{\delta}$	-0.82* (-1.72)	-0.18 (-0.24)	-0.50 (-0.91)	0.14 (0.35)	-0.19 (-0.37)	-0.35 (-0.77)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	34%	55%	28%	25%	32%	40%
	1 yr. % adj.	90%	99%	83%	80%	88%	94%
SAFEX	$\hat{\gamma}$	-0.08** (-1.93)	-0.20*** (-3.33)	-0.09*** (-2.26)	-0.05 (-1.50)	-0.13** (-2.52)	-0.16*** (-3.01)
	$\hat{\delta}$	-0.29 (-0.84)	0.27 (0.52)	0.05 (0.13)	-0.26 (-0.96)	-0.52* (-1.97)	-0.19 (-0.61)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	16%	36%	18%	10%	24%	29%
	1 yr. % adj.	62%	92%	67%	44%	77%	85%

The note below the first section of the table includes a description of table contents.

Table 3E-2: World rice price transmission ECM model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
World Bank (Thai A1)	$\hat{\gamma}$	-0.30***	-0.22***	-0.24***	-0.16***	-0.21***	-0.23***
		(-5.30)	(-4.14)	(-4.39)	(-3.84)	(-3.55)	(-4.46)
	$\hat{\delta}$	-0.03	-0.19	0.94***	0.41*	-0.29	0.09
		(-0.09)	(-0.54)	(3.02)	(1.83)	(-0.53)	(0.32)
	1 mo. % adj.	0	0	94%	0	0	0
	3 mo. % adj.	51%	40%	96%	30%	37%	41%
	1 yr. % adj.	98%	94%	100%	86%	92%	94%
FAO (Thai A1 Super)	$\hat{\gamma}$	-0.30***	-0.22***	-0.24***	-0.15***	-0.21***	-0.24***
		(-5.13)	(-4.12)	(-4.36)	(-3.54)	(-3.56)	(-4.46)
	$\hat{\delta}$	0.14	-0.19	0.85***	0.47***	-0.19	0.21
		(0.48)	(-0.53)	(2.62)	(2.06)	(-0.36)	(0.75)
	1 mo. % adj.	0	0	85%	47%	0	0
	3 mo. % adj.	50%	39%	91%	62%	37%	42%
	1 yr. % adj.	98%	94%	99%	91%	92%	95%
World Bank (Thai 5% broken)	$\hat{\gamma}$	-0.39***	-0.23***	-0.39***	-0.23***	-0.27***	-0.31***
		(-6.07)	(-3.90)	(-5.79)	(-4.55)	(-4.24)	(-4.81)
	$\hat{\delta}$	0.01	0.01	0.89***	0.43**	0.52	0.23
		(0.02)	(0.03)	(3.77)	(2.48)	(1.13)	(1.07)
	1 mo. % adj.	0	0	89%	43%	0	0
	3 mo. % adj.	63%	40%	96%	67%	48%	52%
	1 yr. % adj.	100%	94%	100%	97%	97%	98%
IMF (Thai 5% broken)	$\hat{\gamma}$	-0.37***	-0.21***	-0.36***	-0.21***	-0.25***	-0.29***
		(-6.04)	(-3.76)	(-5.62)	(-4.33)	(-3.91)	(-4.77)
	$\hat{\delta}$	-0.02	-0.04	0.68***	0.33**	0.98**	0.10
		(-0.11)	(-0.17)	(3.28)	(2.13)	(2.29)	(0.57)
	1 mo. % adj.	0	0	0	33%	98%	0
	3 mo. % adj.	61%	38%	87%	58%	99%	50%
	1 yr. % adj.	99%	93%	100%	95%	100%	98%
World Bank (Thai 25% broken)	$\hat{\gamma}$	-0.42***	-0.33***	-0.46***	-0.25***	-0.32***	-0.50***
		(-5.12)	(-4.80)	(-6.08)	(-4.08)	(-4.57)	(-6.03)
	$\hat{\delta}$	0.57	0.02	1.23***	0.34	0.16	1.09***
		(1.49)	(0.04)	(3.20)	(1.10)	(0.31)	(3.17)
	1 mo. % adj.	0	0	123%	0	0	109%
	3 mo. % adj.	67%	56%	107%	44%	53%	102%
	1 yr. % adj.	100%	99%	100%	96%	99%	100%
GIEWS International (Thai 100% parboil)	$\hat{\gamma}$	-0.34***	-0.21***	-0.34***	-0.18***	-0.23***	-0.30***
		(-5.38)	(-3.74)	(-5.33)	(-3.77)	(-3.78)	(-4.73)
	$\hat{\delta}$	0.21	-0.04	0.64***	0.41***	0.43	0.29
		(1.01)	(-0.14)	(2.77)	(2.44)	(1.02)	(1.45)
	1 mo. % adj.	0	0	64%	41%	0	0
	3 mo. % adj.	57%	38%	85%	61%	40%	52%
	1 yr. % adj.	99%	93%	100%	94%	94%	98%

Note: a description of table contents is included in the first section of table 3E–1.

cont. World rice price transmission ECM model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
FAO (Thai 100%B 2nd grade)	$\hat{\gamma}$	-0.38*** (-5.67)	-0.23*** (-3.94)	-0.38*** (-5.55)	-0.22*** (-4.03)	-0.26*** (-3.99)	-0.32*** (-4.87)
	$\hat{\delta}$	0.21 (0.92)	-0.01 (-0.04)	0.86*** (3.38)	0.51*** (2.75)	0.32*** (0.67)	0.25 (1.13)
	1 mo. % adj.	0	0	86%	51%	0	0
	3 mo. % adj.	61%	40%	94%	69%	45%	54%
	1 yr. % adj.	99%	94%	100%	96%	96%	99%
World Bank (Vietnam 5% broken)	$\hat{\gamma}$	-0.34*** (-3.75)	-0.37*** (-3.88)	-0.49*** (-5.49)	-0.25*** (-3.17)	-0.31*** (-3.27)	-0.48*** (-5.09)
	$\hat{\delta}$	0.53* (1.77)	0.12 (0.21)	0.49 (1.11)	0.19 (0.52)	0.24 (0.50)	0.66 (1.66)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	56%	60%	73%	44%	52%	73%
	1 yr. % adj.	99%	99%	100%	96%	98%	100%
GIEWS International (Vietnam 5% broken)	$\hat{\gamma}$	-0.29*** (-5.11)	-0.18*** (-3.57)	-0.24*** (-4.31)	-0.15*** (-3.58)	-0.22*** (-3.56)	-0.23*** (-4.30)
	$\hat{\delta}$	0.38* (1.85)	-0.07 (-0.24)	0.90*** (3.85)	0.44** (2.61)	0.02 (0.05)	0.11 (0.53)
	1 mo. % adj.	0	0	90%	44%	0	0
	3 mo. % adj.	50%	34%	94%	60%	39%	40%
	1 yr. % adj.	98%	89%	100%	91%	93%	94%
GIEWS International (Vietnam 25% broken)	$\hat{\gamma}$	-0.29*** (-4.95)	-0.19*** (-3.71)	-0.23*** (-4.28)	-0.15*** (-3.54)	-0.22*** (-3.61)	-0.22*** (-4.20)
	$\hat{\delta}$	0.40* (1.72)	-0.10 (-0.32)	0.98*** (3.78)	0.45** (2.38)	0.16 (0.42)	0.11 (0.48)
	1 mo. % adj.	0	0	98%	45%	0	0
	3 mo. % adj.	49%	34%	99%	60%	40%	39%
	1 yr. % adj.	98%	90%	100%	90%	94%	93%
GIEWS International (US)	$\hat{\gamma}$	-0.29*** (-4.74)	-0.21*** (-3.87)	-0.30*** (-4.91)	-0.16*** (-3.42)	-0.22*** (-3.92)	-0.26*** (-4.45)
	$\hat{\delta}$	0.57** (2.16)	-0.01 (-0.04)	0.46 (1.51)	0.26 (1.17)	-0.04 (-0.10)	0.15 (0.61)
	1 mo. % adj.	57%	0	0	0	0	0
	3 mo. % adj.	79%	38%	52%	29%	40%	46%
	1 yr. % adj.	99%	93%	98%	85%	94%	97%

Note: a description of table contents is included in the first section of table 3E–1.

cont. World rice price transmission ECM model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
GIEWS International (Uruguay)	$\hat{\gamma}$	-0.40*** (-3.95)	-0.32*** (-3.28)	-0.42*** (-3.91)	-0.39*** (-3.87)	-0.41*** (-3.29)	-0.40*** (-4.11)
	$\hat{\delta}$	0.70*** (3.89)	0.18 (0.52)	0.86*** (2.95)	0.34 (1.56)	0.10 (0.17)	0.41* (1.75)
	1 mo. % adj.	70%	0	86%	0	0	0
	3 mo. % adj.	89%	53%	95%	62%	65%	64%
	1 yr. % adj.	100%	98%	100%	100%	100%	100%
GIEWS International (India 25% broken)	$\hat{\gamma}$	-0.53*** (-4.62)	-0.40*** (-3.85)	-0.33*** (-3.38)	-0.37*** (-3.60)	-0.27*** (-2.96)	-0.69*** (-5.15)
	$\hat{\delta}$	1.67 (1.16)	0.69 (0.47)	1.02 (0.89)	1.00 (0.87)	0.27 (0.25)	0.16 (0.08)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	78%	64%	55%	61%	46%	91%
	1 yr. % adj.	100%	100%	99%	99%	97%	100%

Note: a description of table contents is included in the first section of table 3E–1.

Table 3E-3: World rice to local rice price transmission ECM model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
World Bank (Thai A1)	$\hat{\gamma}$	-0.16*** (-2.98)	-0.41*** (-5.41)	-0.18*** (-3.84)	-0.29*** (-4.82)	-0.21*** (-3.81)	-0.26*** (-4.29)
	$\hat{\delta}$	0.20 (0.72)	0.19 (0.43)	0.16 (0.77)	0.13 (0.43)	-0.01 (-0.02)	0.32 (1.24)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	29%	65%	33%	49%	38%	45%
	1 yr. % adj.	85%	100%	89%	98%	93%	96%
FAO (Thai A1 Super)	$\hat{\gamma}$	-0.15*** (-2.91)	-0.40*** (-5.45)	-0.19*** (-4.07)	-0.29*** (-4.91)	-0.21*** (-3.70)	-0.24*** (-4.04)
	$\hat{\delta}$	0.04 (0.13)	0.11 (0.25)	0.02 (0.08)	0.05 (0.18)	0.04 (0.14)	0.52* (1.96)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	28%	64%	35%	50%	37%	43%
	1 yr. % adj.	83%	100%	90%	98%	92%	95%
World Bank (Thai 5% broken)	$\hat{\gamma}$	-0.24*** (-3.65)	-0.45*** (-5.83)	-0.28*** (-4.62)	-0.38*** (-5.64)	-0.24*** (-4.24)	-0.32*** (-4.73)
	$\hat{\delta}$	0.26 (1.20)	0.05 (0.13)	0.26 (1.53)	0.06 (0.27)	-0.05 (-0.17)	0.38* (1.90)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	42%	70%	48%	61%	42%	54%
	1 yr. % adj.	95%	100%	97%	99%	95%	99%
IMF (Thai 5% broken)	$\hat{\gamma}$	-0.22*** (-3.49)	-0.44*** (-5.68)	-0.25*** (-4.33)	-0.34*** (-5.31)	-0.21*** (-3.76)	-0.31*** (-4.68)
	$\hat{\delta}$	0.14 (0.75)	0.12 (0.39)	0.21 (1.42)	0.15 (0.75)	0.14 (0.55)	0.31* (1.79)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	38%	68%	44%	56%	38%	52%
	1 yr. % adj.	93%	100%	96%	99%	93%	98%
World Bank (Thai 25% broken)	$\hat{\gamma}$	-0.26*** (-3.32)	-0.62*** (-7.27)	-0.39*** (-5.69)	-0.42*** (-5.51)	-0.27*** (-4.47)	-0.47*** (-6.07)
	$\hat{\delta}$	0.13 (0.32)	0.66 (1.16)	0.45* (1.79)	0.08 (0.22)	-0.05 (-0.15)	0.99*** (3.17)
	1 mo. % adj.	0	0	0	0	0	99%
	3 mo. % adj.	45%	86%	62%	67%	47%	100%
	1 yr. % adj.	96%	100%	100%	100%	97%	100%
GIEWS International (Thai 100% parboil)	$\hat{\gamma}$	-0.20*** (-3.33)	-0.44*** (-5.79)	-0.27*** (-4.72)	-0.36*** (-5.50)	-0.19*** (-3.53)	-0.29*** (-4.39)
	$\hat{\delta}$	0.21 (0.99)	0.09 (0.27)	-0.00 (-0.03)	-0.02 (-0.09)	0.20 (0.80)	0.44** (2.29)
	1 mo. % adj.	0	0	0	0	0	44%
	3 mo. % adj.	36%	68%	46%	59%	34%	72%
	1 yr. % adj.	91%	100%	97%	99%	90%	99%

Note: a description of table contents is included in the first section of table 3E–1.

cont. World rice to local rice price transmission ECM model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
FAO (Thai 100%B 2nd grade)	$\hat{\gamma}$	-0.22*** (-3.53)	-0.45*** (-5.90)	-0.29*** (-4.93)	-0.39*** (-5.78)	-0.23*** (-4.14)	-0.32*** (-4.62)
	$\hat{\delta}$	0.25 (1.07)	-0.17 (-0.45)	0.08 (0.46)	-0.01 (-0.04)	-0.04 (-0.16)	0.39* (1.82)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	39%	70%	50%	62%	41%	53%
	1 yr. % adj.	94%	100%	98%	100%	94%	98%
World Bank (Vietnam 5% broken)	$\hat{\gamma}$	-0.40*** (-3.89)	-0.66*** (-5.81)	-0.38*** (-5.44)	-0.59*** (-6.18)	-0.24*** (-3.31)	-0.46*** (-4.87)
	$\hat{\delta}$	0.74* (1.67)	0.55 (0.80)	-0.25 (-0.83)	-0.17 (-0.41)	-0.40 (-1.49)	0.12 (0.32)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	64%	88%	62%	83%	42%	71%
	1 yr. % adj.	100%	100%	99%	100%	95%	100%
GIEWS International (Vietnam 5% broken)	$\hat{\gamma}$	-0.16*** (-3.09)	-0.38*** (-5.21)	-0.19*** (-4.04)	-0.29*** (-4.90)	-0.19*** (-3.71)	-0.25*** (-4.15)
	$\hat{\delta}$	0.29 (1.41)	-0.15 (-0.43)	0.02 (0.13)	0.19 (0.86)	-0.37 (-1.59)	0.22 (1.10)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	30%	61%	35%	50%	35%	43%
	1 yr. % adj.	86%	99%	90%	98%	91%	95%
GIEWS International (Vietnam 25% broken)	$\hat{\gamma}$	-0.16*** (-2.96)	-0.38*** (-5.30)	-0.20*** (-4.26)	-0.29*** (-5.04)	-0.20*** (-3.87)	-0.25*** (-4.18)
	$\hat{\delta}$	0.31 (1.35)	-0.20 (-0.52)	0.02 (0.12)	0.12 (0.50)	-0.30 (-1.38)	0.18 (0.82)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	29%	62%	35%	50%	36%	43%
	1 yr. % adj.	84%	99%	91%	98%	92%	95%
GIEWS International (US)	$\hat{\gamma}$	-0.19*** (-3.61)	-0.42*** (-5.83)	-0.26*** (-4.81)	-0.36*** (-5.48)	-0.19*** (-3.89)	-0.28*** (-4.47)
	$\hat{\delta}$	0.21 (0.83)	-0.72* (-1.74)	0.07 (0.37)	0.07 (0.26)	-0.17 (-0.82)	0.11 (0.46)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	35%	67%	45%	57%	34%	48%
	1 yr. % adj.	90%	100%	96%	99%	89%	97%

Note: a description of table contents is included in the first section of table 3E–1.

cont. World rice to local rice price transmission ECM model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
GIEWS International (Uruguay)	$\hat{\gamma}$	-0.37*** (-3.41)	-0.60*** (-4.96)	-0.33*** (-3.70)	-0.51*** (-4.60)	-0.31*** (-2.95)	-0.38*** (-3.69)
	$\hat{\delta}$	0.21 (0.77)	0.01 (0.02)	0.04 (0.21)	0.13 (0.55)	-0.07 (-0.21)	0.47** (2.05)
	1 mo. % adj.	0	0	0	0	0	47%
	3 mo. % adj.	61%	84%	54%	76%	53%	80%
	1 yr. % adj.	99%	100%	99%	100%	98%	100%
GIEWS International (India 25% broken)	$\hat{\gamma}$	-0.30*** (-3.17)	-0.66*** (-5.26)	-0.22*** (-2.92)	-0.37*** (-3.74)	-0.28*** (-3.36)	-0.74*** (-5.25)
	$\hat{\delta}$	0.47 (0.37)	1.73 (1.13)	0.37 (0.52)	-0.34 (-0.43)	-0.36 (-0.56)	-1.89 (-1.07)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	51%	89%	40%	61%	48%	93%
	1 yr. % adj.	98%	100%	94%	99%	97%	100%

Note: a description of table contents is included in the first section of table 3E–1.

Table 3E-4: World sorghum and millet price transmission ECM model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
				Sorghum			
World Bank (US Gulf)	$\hat{\gamma}$	-0.19***	-0.19***	-0.17***	-0.11***	-0.14***	-0.13***
		(-3.66)	(-3.64)	(-3.37)	(-3.00)	(-2.76)	(-2.73)
	$\hat{\delta}$	-0.26	0.45	0.64	-0.32	0.04	0.49
		(-0.46)	(0.72)	(1.17)	(-0.84)	(0.09)	(1.63)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	35%	34%	31%	21%	25%	25%
	1 yr. % adj.	90%	90%	87%	72%	80%	79%
FAO (US Gulf)	$\hat{\gamma}$	-0.19***	-0.22***	-0.18***	-0.11***	-0.14***	-0.14***
		(-3.58)	(-3.92)	(-3.41)	(-2.91)	(-2.78)	(-2.85)
	$\hat{\delta}$	-0.24	0.36	0.69	-0.36	0.12	0.53*
		(-0.42)	(0.55)	(1.26)	(-0.93)	(0.26)	(1.77)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	35%	38%	32%	21%	26%	26%
	1 yr. % adj.	91%	93%	88%	72%	81%	81%
GIEWS International (US Gulf)	$\hat{\gamma}$	-0.19***	-0.21***	-0.18***	-0.11***	-0.14***	-0.14***
		(-3.63)	(-3.79)	(-3.40)	(-2.88)	(-2.79)	(-2.87)
	$\hat{\delta}$	-0.46	0.52	0.85	-0.28	0.38	0.47
		(-0.80)	(0.83)	(1.50)	(-0.69)	(0.79)	(1.51)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	36%	37%	32%	21%	26%	26%
	1 yr. % adj.	91%	92%	88%	72%	81%	81%
				Millet			
World Bank (US Gulf)	$\hat{\gamma}$	-0.26***	-0.11**	-0.12**	-0.12**	-0.12**	-0.08*
		(-4.25)	(-2.36)	(-2.20)	(-2.59)	(-2.61)	(-1.91)
	$\hat{\delta}$	-0.43	0.58	0.47	0.04	0.22	0.25
		(-0.59)	(0.89)	(0.65)	(0.08)	(0.50)	(0.57)
	1 mo. % adj.	0	0	0	0	0	-
	3 mo. % adj.	46%	21%	23%	22%	23%	-
	1 yr. % adj.	97%	72%	76%	75%	76%	-
FAO (US Gulf)	$\hat{\gamma}$	-0.26***	-0.12**	-0.12**	-0.13***	-0.12**	-0.08**
		(-4.27)	(-2.53)	(-2.20)	(-2.65)	(-2.60)	(-1.99)
	$\hat{\delta}$	-0.30	0.60	0.71	0.33	-0.15	0.19
		(-0.40)	(0.91)	(0.98)	(0.60)	(-0.33)	(0.42)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	46%	23%	23%	24%	23%	16%
	1 yr. % adj.	97%	77%	76%	78%	77%	61%
GIEWS International (US Gulf)	$\hat{\gamma}$	-0.26***	-0.12**	-0.12**	-0.13***	-0.12**	-0.08**
		(-4.28)	(-2.50)	(-2.16)	(-2.66)	(-2.71)	(-2.01)
	$\hat{\delta}$	-0.31	0.44	0.45	0.40	-0.17	0.20
		(-0.41)	(0.67)	(0.62)	(0.72)	(-0.37)	(0.46)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	46%	23%	22%	24%	23%	16%
	1 yr. % adj.	97%	76%	75%	78%	77%	61%

Note: a description of table contents is included in the first section of table 3E–1.

Table 3E-5: World cassava price transmission ECM model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
GIEWS International (Bangkok, Thailand)	$\hat{\gamma}$	-0.27***	-0.51***	-0.38***	-0.19***	-0.17***	-0.38***
		(-4.23)	(-6.42)	(-4.97)	(-3.62)	(-3.35)	(-4.84)
	$\hat{\delta}$	1.03***	0.22	1.26***	0.06	0.49	0.77**
		(2.86)	(0.44)	(2.86)	(0.21)	(1.60)	(2.17)
	1 mo. % adj.	103%	0	126%	0	0	77%
	3 mo. % adj.	101%	76%	110%	34%	31%	91%
	1 yr. % adj.	100%	100%	100%	90%	88%	100%

Note: a description of table contents is included in the first section of table 3E–1.

Table 3E-6: Neighboring country maize price transmission ECM model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Randfontein, South Africa	$\hat{\gamma}$	-0.09** (-2.30)	-0.22*** (-3.79)	-0.11** (-2.56)	-0.07* (-2.30)	-0.15*** (-2.99)	-0.16*** (-3.07)
	$\hat{\delta}$	-0.11 (-0.31)	0.82 (1.61)	0.14 (0.38)	0.11 (0.39)	-0.51* (-1.87)	0.04 (0.13)
	1 mo. % adj.	0	0	0	-	0	0
	3 mo. % adj.	18%	39%	20%	-	27%	30%
	1 yr. % adj.	66%	94%	71%	-	82%	86%
Cotonou, Benin	$\hat{\gamma}$	-0.20*** (-3.95)	-0.29*** (-4.37)	-0.13*** (-3.02)	-0.22*** (-4.42)	-0.46*** (-6.53)	-0.37*** (-5.61)
	$\hat{\delta}$	0.07 (0.74)	0.12 (0.81)	0.10 (0.96)	0.10 (1.33)	0.06 (0.72)	-0.05 (-0.62)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	35%	50%	25%	46%	71%	61%
	1 yr. % adj.	91%	98%	79%	94%	100%	99%
Malanville, Benin	$\hat{\gamma}$	-0.26*** (-4.37)	-0.26*** (-3.49)	-0.12** (-2.61)	-0.24*** (-3.78)	-0.55*** (-6.57)	-0.46*** (-5.69)
	$\hat{\delta}$	-0.05 (-0.42)	0.08 (0.38)	-0.21* (-1.70)	0.13 (1.27)	0.23** (2.10)	0.13 (1.42)
	1 mo. % adj.	0	0	0	0	23%	0
	3 mo. % adj.	43%	45%	22%	42%	85%	71%
	1 yr. % adj.	96%	96%	75%	95%	100%	100%
Accra, Ghana	$\hat{\gamma}$	-0.29*** (-3.31)	-0.48*** (-4.06)	-0.36*** (-3.69)	-0.08 (-1.60)	-0.47*** (-4.50)	-0.41*** (-4.29)
	$\hat{\delta}$	0.11 (0.69)	0.03 (0.13)	0.03 (0.17)	-0.01 (-0.13)	0.03 (0.22)	0.02 (0.15)
	1 mo. % adj.	0	0	0	-	0	0
	3 mo. % adj.	49%	73%	58%	-	72%	65%
	1 yr. % adj.	98%	100%	99%	-	100%	100%
Bolgatanga, Ghana	$\hat{\gamma}$	-0.24*** (-3.03)	-0.46*** (-4.10)	-0.33*** (-3.61)	-0.09** (-2.02)	-0.37*** (-3.74)	-0.33*** (-3.51)
	$\hat{\delta}$	0.34* (1.70)	0.14 (0.44)	-0.19 (-0.80)	-0.08 (-0.72)	-0.03 (-0.16)	0.19 (1.00)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	43%	71%	54%	17%	60%	55%
	1 yr. % adj.	95%	100%	99%	65%	99%	99%
Lomé, Togo	$\hat{\gamma}$	-0.29*** (-4.59)	-0.45*** (-5.74)	-0.19*** (-3.82)	-0.24*** (-4.38)	-0.40*** (-5.24)	-0.45*** (-6.07)
	$\hat{\delta}$	0.30*** (3.48)	0.13 (0.94)	-0.08 (-0.77)	0.05 (0.65)	0.19** (2.20)	0.11 (1.33)
	1 mo. % adj.	30%	0	0	0	19%	0
	3 mo. % adj.	66%	70%	34%	42%	70%	70%
	1 yr. % adj.	98%	100%	90%	95%	100%	100%

Note: a description of table contents is included in the first section of table 3E–1.

cont. Neighboring country maize price transmission ECM model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Korbongou, Togo	$\hat{\gamma}$	-0.18*** (-3.59)	-0.33*** (-4.95)	-0.15*** (-3.48)	-0.22*** (-4.59)	-0.53*** (-6.31)	-0.36*** (-5.17)
	$\hat{\delta}$	0.09 (0.71)	0.10 (0.55)	-0.08 (-0.63)	0.07 (0.70)	0.38*** (4.15)	0.22** (2.02)
	1 mo. % adj.	0	0	0	0	38%	22%
	3 mo. % adj.	32%	55%	28%	39%	86%	68%
	1 yr. % adj.	88%	99%	83%	93%	100%	99%
Niamey, Niger	$\hat{\gamma}$	-0.27*** (-4.20)	-0.42*** (-5.65)	-0.20*** (-4.14)	-0.29*** (-4.94)	-0.46*** (-5.55)	-0.47*** (-5.76)
	$\hat{\delta}$	0.33* (1.83)	-0.10 (-0.39)	-0.16 (-0.85)	0.05 (0.32)	0.61*** (4.22)	0.52*** (3.23)
	1 mo. % adj.	0	0	0	0	61%	52%
	3 mo. % adj.	47%	67%	36%	49%	89%	86%
	1 yr. % adj.	97%	100%	91%	98%	100%	100%
Maradi, Niger	$\hat{\gamma}$	-0.26*** (-4.38)	-0.41*** (-5.52)	-0.20*** (-4.11)	-0.31*** (-5.60)	-0.61*** (-6.86)	-0.48*** (-5.83)
	$\hat{\delta}$	0.32** (1.98)	0.02 (0.08)	-0.17 (-0.94)	0.08 (0.59)	0.51*** (4.26)	0.51*** (3.59)
	1 mo. % adj.	32%	0	0	0	51%	51%
	3 mo. % adj.	62%	65%	36%	53%	93%	87%
	1 yr. % adj.	97%	100%	91%	98%	100%	100%
N'Djamena, Chad	$\hat{\gamma}$	-0.23*** (-3.23)	-0.42*** (-5.16)	-0.22*** (-3.57)	-0.15*** (-2.87)	-0.46*** (-4.75)	-0.45*** (-5.04)
	$\hat{\delta}$	0.21 (1.46)	-0.31 (-1.46)	-0.02 (-0.10)	0.09 (0.83)	0.25** (2.27)	0.40*** (3.12)
	1 mo. % adj.	0	0	0	0	25%	40%
	3 mo. % adj.	40%	56%	39%	28%	79%	82%
	1 yr. % adj.	94%	100%	93%	84%	100%	100%
Yaoundé, Cameroon	$\hat{\gamma}$	-0.25*** (-2.79)	-0.81*** (-6.92)	-0.46*** (-4.67)	-0.09 (-1.49)	-0.27*** (-2.93)	-0.35*** (-3.71)
	$\hat{\delta}$	0.26 (1.00)	0.36 (1.10)	-0.06 (-0.20)	-0.14 (-0.74)	-0.16 (-0.77)	-0.04 (-0.16)
	1 mo. % adj.	0	0	0	-	0	0
	3 mo. % adj.	44%	97%	71%	-	47%	57%
	1 yr. % adj.	96%	100%	100%	-	97%	99%
Garoua, Cameroon	$\hat{\gamma}$	-0.14*** (-1.91)	-0.52*** (-5.02)	-0.26*** (-3.30)	-0.12** (-2.28)	-0.40*** (-3.72)	-0.42*** (-4.28)
	$\hat{\delta}$	0.13 (0.78)	0.09 (0.38)	0.24 (1.25)	0.31*** (2.84)	0.54*** (5.33)	0.49*** (3.45)
	1 mo. % adj.	-	0	0	31%	54%	49%
	3 mo. % adj.	-	77%	45%	47%	84%	83%
	1 yr. % adj.	-	100%	96%	83%	100%	100%

Note: a description of table contents is included in the first section of table 3E–1.

cont. Neighboring country maize price transmission ECM model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Bamako, Mali	$\hat{\gamma}$	-0.23**	-0.62***	-0.52***	-0.05	-0.40**	-0.37***
		(-2.11)	(-4.45)	(-4.41)	(-1.14)	(-2.62)	(-3.15)
	$\hat{\delta}$	0.35	0.06	-0.44	-0.10	0.86***	0.40
		(0.93)	(0.13)	(-1.11)	(-0.58)	(3.87)	(1.15)
	1 mo. % adj.	0	0	0	-	86%	0
	3 mo. % adj.	40%	85%	77%	-	95%	61%
	1 yr. % adj.	94%	100%	100%	-	100%	99%
Mopti, Mali	$\hat{\gamma}$	-0.18***	-0.40***	-0.18***	-0.15***	-0.41***	-0.38***
		(-2.69)	(-4.60)	(-3.18)	(-2.73)	(-4.25)	(-4.39)
	$\hat{\delta}$	0.54**	0.23	0.11	0.12	0.15	0.48*
		(2.04)	(0.61)	(0.39)	(0.64)	(0.72)	(1.95)
	1 mo. % adj.	54%	0	0	0	0	0
	3 mo. % adj.	69%	64%	33%	28%	65%	62%
	1 yr. % adj.	95%	100%	89%	83%	100%	100%

Note: a description of table contents is included in the first section of table 3E–1.

Table 3E-7: Neighboring country rice price transmission ECM model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
Cotonou, Benin	$\hat{\gamma}$	-0.31*** (-4.67)	-0.28*** (-4.36)	-0.32*** (-4.97)	-0.16*** (-3.08)	-0.19*** (-3.44)	-0.27*** (-4.09)
	$\hat{\delta}$	0.24 (1.37)	0.02 (0.10)	0.13 (0.63)	0.13 (0.88)	-0.05 (-0.27)	0.28 (1.63)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	52%	48%	54%	29%	35%	47%
	1 yr. % adj.	98%	97%	99%	85%	90%	97%
Accra, Ghana	$\hat{\gamma}$	-0.30*** (-2.92)	-0.40*** (-3.71)	-0.44*** (-3.66)	-0.20** (-2.27)	-0.19** (-1.75)	-0.65*** (-5.58)
	$\hat{\delta}$	0.62*** (3.69)	-0.17 (-0.57)	0.51 (1.63)	0.35** (2.23)	-0.28 (-0.83)	0.23 (1.11)
	1 mo. % adj.	62%	0	0	35%	-	0
	3 mo. % adj.	81%	64%	69%	58%	-	88%
	1 yr. % adj.	99%	100%	100%	94%	-	100%
Bolgatanga, Ghana	$\hat{\gamma}$	-0.18** (-2.06)	-0.39*** (-3.07)	-0.33*** (-3.19)	-0.10 (-1.47)	-0.14 (-1.60)	-0.26** (-2.40)
	$\hat{\delta}$	0.23 (1.53)	0.48* (1.98)	0.02 (0.06)	-0.13 (-1.09)	0.41** (2.55)	0.11 (0.55)
	1 mo. % adj.	0	0	0	-	-	0
	3 mo. % adj.	33%	80%	55%	-	-	45%
	1 yr. % adj.	89%	100%	99%	-	-	96%
Lomé, Togo	$\hat{\gamma}$	-0.23*** (-3.91)	-0.20*** (-3.65)	-0.16*** (-2.93)	-0.11*** (-2.54)	-0.12*** (-2.80)	-0.22*** (-3.71)
	$\hat{\delta}$	0.14** (2.31)	0.01 (0.14)	-0.12 (-1.58)	0.05 (1.03)	-0.07 (-0.87)	-0.01 (-0.25)
	1 mo. % adj.	14%	0	0	0	0	0
	3 mo. % adj.	49%	36%	30%	21%	23%	38%
	1 yr. % adj.	95%	92%	86%	73%	77%	93%
Korbongou, Togo	$\hat{\gamma}$	-0.31*** (-4.40)	-0.25*** (-4.10)	-0.41*** (-5.94)	-0.20*** (-3.51)	-0.19*** (-3.06)	-0.23*** (-3.53)
	$\hat{\delta}$	0.21 (1.60)	0.04 (0.29)	0.33** (2.40)	0.13 (1.29)	0.29** (2.40)	0.50*** (4.27)
	1 mo. % adj.	0	0	33%	0	29%	50%
	3 mo. % adj.	53%	43%	77%	36%	53%	70%
	1 yr. % adj.	98%	96%	100%	92%	93%	97%
Ouagadougou, Burkina Faso	$\hat{\gamma}$	-0.59*** (-4.69)	-0.32*** (-3.10)	-0.66*** (-5.54)	-0.60*** (-4.88)	-0.59*** (-4.40)	-0.565*** (-4.76)
	$\hat{\delta}$	0.31 (1.63)	0.04 (0.13)	0.02 (0.06)	0.23 (1.11)	0.25 (0.57)	0.25 (1.08)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	83%	54%	89%	84%	83%	81%
	1 yr. % adj.	100%	99%	100%	100%	100%	100%

Note: a description of table contents is included in the first section of table 3E–1.

cont. Neighboring country rice price transmission ECM model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Dori, Burkina Faso	$\hat{\gamma}$	-0.58***	-0.39***	-0.75***	-0.70***	-0.67***	-0.64***
		(-4.76)	(-3.61)	(-6.04)	(-5.59)	(-4.83)	(-5.29)
	$\hat{\delta}$	0.55*	-0.19	0.38	0.31	0.26	0.41
		(1.88)	(-0.36)	(0.93)	(1.00)	(0.50)	(1.17)
	1 mo. % adj.	55%	0	0	0	0	0
	3 mo. % adj.	92%	62%	94%	91%	89%	87%
	1 yr. % adj.	100%	100%	100%	100%	100%	100%
Niamey, Niger	$\hat{\gamma}$	-0.46***	-0.32***	-0.56***	-0.30***	-0.35***	-0.45***
		(-5.80)	(-4.58)	(-6.85)	(-4.47)	(-4.87)	(-5.58)
	$\hat{\delta}$	0.29	0.12	0.53**	0.16	0.19	0.31
		(1.30)	(0.42)	(2.20)	(0.84)	(0.75)	(1.45)
	1 mo. % adj.	0	0	53%	0	0	0
	3 mo. % adj.	71%	53%	90%	50%	58%	70%
	1 yr. % adj.	100%	98%	100%	98%	99%	100%
Maradi, Niger	$\hat{\gamma}$	-0.39***	-0.30***	-0.43***	-0.24***	-0.34***	-0.34***
		(-5.14)	(-4.37)	(-5.83)	(-3.99)	(-4.65)	(-4.61)
	$\hat{\delta}$	0.17	-0.17	0.24	0.04	0.09	0.12
		(0.76)	(-0.61)	(0.96)	(0.21)	(0.36)	(0.56)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	63%	50%	68%	43%	56%	56%
	1 yr. % adj.	100%	98%	100%	95%	99%	99%
N'Djamena, Chad	$\hat{\gamma}$	-0.26***	-0.21***	-0.25***	-0.12**	-0.21***	-0.23***
		(-3.45)	(-2.89)	(-3.24)	(-2.16)	(-3.43)	(-3.51)
	$\hat{\delta}$	0.13	-0.01	0.20*	0.06	0.07	0.10
		(1.40)	(-0.08)	(1.78)	(0.80)	(0.93)	(1.22)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	53%	37%	44%	23%	38%	41%
	1 yr. % adj.	97%	92%	96%	76%	93%	94%
Yaoundé, Cameroon	$\hat{\gamma}$	-0.55***	-0.35***	-0.54***	-0.51***	-0.47***	-0.38***
		(-4.97)	(-3.57)	(-5.37)	(-4.67)	(-4.08)	(-3.96)
	$\hat{\delta}$	0.26	0.13	0.20	0.36	0.34	0.39
		(0.83)	(0.32)	(0.59)	(1.40)	(0.98)	(1.34)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	79%	58%	79%	76%	72%	62%
	1 yr. % adj.	100%	99%	100%	100%	100%	99%
Garoua, Cameroon	$\hat{\gamma}$	-0.66***	-0.37***	-0.57***	-0.58***	-0.58***	-0.43***
		(-5.96)	(-3.93)	(-5.54)	(-5.58)	(-4.78)	(-4.50)
	$\hat{\delta}$	0.54**	0.11	0.61**	0.34*	0.33	0.33
		(2.42)	(0.37)	(2.32)	(1.85)	(1.12)	(1.54)
	1 mo. % adj.	54%	0	61%	0	0	0
	3 mo. % adj.	95%	61%	93%	89%	83%	78%
	1 yr. % adj.	100%	99%	100%	100%	100%	100%

Note: a description of table contents is included in the first section of table 3E–1.

cont. Neighboring country rice price transmission ECM model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Bamako, Mali	$\hat{\gamma}$	-0.51***	-0.37***	-0.68***	-0.69***	-0.55***	-0.55***
		(-4.57)	(-3.64)	(-5.53)	(-5.70)	(-4.38)	(-4.78)
	$\hat{\delta}$	0.42**	0.46	0.70**	0.48**	0.41	0.56**
		(2.23)	(1.46)	(2.60)	(2.48)	(1.37)	(2.51)
	1 mo. % adj.	42%	0	70%	48%	0	56%
	3 mo. % adj.	86%	61%	97%	95%	88%	91%
	1 yr. % adj.	100%	99%	100%	100%	100%	100%
Mopti, Mali	$\hat{\gamma}$	-0.51***	-0.26**	-0.75***	-0.48***	-0.55***	-0.53***
		(-4.05)	(-2.57)	(-5.28)	(-3.66)	(-3.38)	(-4.23)
	$\hat{\delta}$	0.32	-0.30	0.96**	0.36	0.82*	0.52
		(1.26)	(-0.67)	(2.26)	(1.52)	(1.80)	(1.49)
	1 mo. % adj.	0	0	96%	0	0	0
	3 mo. % adj.	76%	45%	100%	73%	96%	78%
	1 yr. % adj.	100%	96%	100%	100%	100%	100%

Note: a description of table contents is included in the first section of table 3E–1.

Table 3E-8: Neighboring country rice to local rice price transmission ECM model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
Cotonou, Benin	$\hat{\gamma}$	-0.22*** (-3.72)	-0.53*** (-6.38)	-0.23*** (-3.89)	-0.33*** (-4.66)	-0.16*** (-2.88)	-0.36*** (-4.89)
	$\hat{\delta}$	0.13 (0.75)	0.21 (0.80)	0.08 (0.60)	0.12 (0.63)	0.01 (0.12)	0.27* (1.69)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	39%	77%	40%	55%	29%	59%
	1 yr. % adj.	93%	100%	94%	99%	85%	99%
Accra, Ghana	$\hat{\gamma}$	-0.30*** (-2.94)	-0.59*** (-4.55)	-0.40*** (-3.76)	-0.63*** (-4.68)	-0.20** (-2.12)	-0.41*** (-3.48)
	$\hat{\delta}$	0.00 (0.01)	-0.25 (-0.65)	0.03 (0.15)	0.42* (1.79)	-0.01 (-0.06)	0.41* (1.71)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	50%	84%	64%	86%	36%	79%
	1 yr. % adj.	98%	100%	100%	100%	91%	100%
Bolgatanga, Ghana	$\hat{\gamma}$	-0.23** (-2.49)	-0.67*** (-4.93)	-0.30*** (-2.83)	-0.49*** (-4.03)	-0.14** (-2.19)	-0.37** (-3.20)
	$\hat{\delta}$	0.31* (1.90)	0.12 (0.42)	0.08 (0.48)	-0.01 (-0.04)	0.09 (1.10)	0.22 (1.15)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	41%	89%	51%	74%	26%	60%
	1 yr. % adj.	95%	100%	98%	100%	81%	99%
Lomé, Togo	$\hat{\gamma}$	-0.15*** (-2.97)	-0.40*** (-5.26)	-0.15*** (-2.85)	-0.26*** (-3.96)	-0.10** (-2.17)	-0.35*** (-5.24)
	$\hat{\delta}$	0.15*** (2.65)	0.01 (0.06)	-0.04 (-0.84)	0.05 (0.80)	-0.02 (-0.36)	-0.01 (-0.14)
	1 mo. % adj.	15%	0	0	0	0	0
	3 mo. % adj.	38%	64%	28%	45%	18%	58%
	1 yr. % adj.	85%	100%	84%	96%	67%	99%
Korbongou, Togo	$\hat{\gamma}$	-0.17*** (-2.74)	-0.54*** (-6.53)	-0.30*** (-4.91)	-0.44*** (-5.81)	-0.17*** (-3.15)	-0.41*** (-5.68)
	$\hat{\delta}$	0.17 (1.39)	0.30 (1.60)	0.22** (2.42)	0.08 (0.63)	0.05 (0.75)	-0.01 (-0.06)
	1 mo. % adj.	0	0	22%	0	0	0
	3 mo. % adj.	31%	78%	62%	68%	31%	65%
	1 yr. % adj.	87%	100%	99%	100%	87%	100%
Ouagadougou, Burkina Faso	$\hat{\gamma}$	-0.71*** (-5.15)	-0.68*** (-5.41)	-0.49*** (-5.11)	-0.65*** (-6.01)	-0.31*** (-2.87)	-0.57*** (-5.28)
	$\hat{\delta}$	0.60*** (2.49)	0.28 (0.78)	-0.15 (-0.92)	-0.39* (-1.96)	0.10 (0.31)	-0.20 (-0.98)
	1 mo. % adj.	60%	0	0	0	0	0
	3 mo. % adj.	97%	90%	74%	88%	53%	82%
	1 yr. % adj.	100%	100%	100%	100%	98%	100%

Note: a description of table contents is included in the first section of table 3E–1.

cont. Neighboring country rice to local rice price transmission ECM model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
Dori, Burkina Faso	$\hat{\gamma}$	-0.74*** (-5.45)	-0.73*** (-5.73)	-0.48*** (-4.56)	-0.71*** (-5.77)	-0.39*** (-3.28)	-0.66*** (-5.47)
	$\hat{\delta}$	0.94** (2.43)	0.31 (0.53)	0.00 (0.01)	-0.10 (-0.29)	0.00 (0.00)	-0.05 (-0.14)
	1 mo. % adj.	94%	0	0	0	0	0
	3 mo. % adj.	100%	93%	73%	91%	63%	88%
	1 yr. % adj.	100%	100%	100%	100%	100%	100%
Niamey, Niger	$\hat{\gamma}$	-0.39*** (-5.09)	-0.61*** (-7.09)	-0.40*** (-5.48)	-0.49*** (-6.23)	-0.24*** (-3.81)	-0.49*** (-6.27)
	$\hat{\delta}$	0.35** (1.64)	0.47 (1.40)	0.45*** (2.73)	0.41* (1.81)	0.31** (2.04)	-0.01 (-0.04)
	1 mo. % adj.	0	0	0	0	31%	0
	3 mo. % adj.	63%	85%	80%	74%	60%	74%
	1 yr. % adj.	100%	100%	100%	100%	97%	100%
Maradi, Niger	$\hat{\gamma}$	-0.32*** (-4.30)	-0.60*** (-7.02)	-0.29*** (-4.46)	-0.42*** (-5.56)	-0.25*** (-3.96)	-0.49*** (-6.22)
	$\hat{\delta}$	0.25 (1.17)	0.32 (0.98)	0.34** (2.05)	0.24 (1.03)	0.07 (0.47)	-0.06 (-0.29)
	1 mo. % adj.	0	0	34%	0	0	0
	3 mo. % adj.	53%	84%	67%	66%	44%	74%
	1 yr. % adj.	98%	100%	98%	100%	96%	100%
N'Djamena, Chad	$\hat{\gamma}$	-0.24*** (-3.31)	-0.57*** (-5.97)	-0.20*** (-3.23)	-0.40*** (-4.98)	-0.17*** (-3.04)	-0.35*** (-4.56)
	$\hat{\delta}$	0.08 (0.90)	0.14 (1.05)	0.07 (1.04)	0.08 (0.87)	0.04 (0.87)	0.24*** (3.31)
	1 mo. % adj.	0	0	0	0	0	24%
	3 mo. % adj.	42%	82%	37%	64%	30%	68%
	1 yr. % adj.	95%	100%	92%	100%	86%	99%
Yaoundé, Cameroon	$\hat{\gamma}$	-0.61*** (-5.06)	-0.75*** (-6.35)	-0.43*** (-4.65)	-0.47*** (-4.50)	-0.25*** (-2.70)	-0.52*** (-5.14)
	$\hat{\delta}$	0.54* (1.77)	0.56 (1.32)	0.30 (1.32)	-0.23 (-0.41)	-0.05 (-0.24)	-0.05 (-0.19)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	85%	94%	68%	71%	43%	77%
	1 yr. % adj.	100%	100%	100%	100%	95%	100%
Garoua, Cameroon	$\hat{\gamma}$	-0.59*** (-4.75)	-0.72*** (-6.25)	-0.36*** (-4.24)	-0.46*** (-4.65)	-0.36*** (-3.67)	-0.58*** (-5.43)
	$\hat{\delta}$	0.29 (1.17)	0.20 (0.59)	0.10 (0.54)	0.21 (1.02)	0.22 (1.25)	0.29 (1.50)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	83%	92%	59%	70%	59%	82%
	1 yr. % adj.	100%	100%	99%	100%	99%	100%

Note: a description of table contents is included in the first section of table 3E–1.

cont. Neighboring country rice to local rice price transmission ECM model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Bamako, Mali	$\hat{\gamma}$	-0.53***	-0.72***	-0.47***	-0.67***	-0.41***	-0.69***
		(-4.34)	(-5.76)	(-4.40)	(-5.67)	(-3.29)	(-5.91)
	$\hat{\delta}$	0.47*	0.23	0.24	0.23	0.58***	0.34*
		(1.87)	(0.65)	(1.41)	(1.08)	(2.90)	(1.73)
	1 mo. % adj.	0	0	0	0	58%	0
	3 mo. % adj.	78%	92%	72%	89%	85%	90%
	1 yr. % adj.	100%	100%	100%	100%	100%	100%
Mopti, Mali	$\hat{\gamma}$	-0.28***	-0.56***	-0.48***	-0.70***	-0.20	-0.64***
		(-2.14)	(-4.15)	(-4.11)	(-5.14)	(-1.68)	(-4.87)
	$\hat{\delta}$	0.23	0.62	0.42	0.03	0.33	0.19
		(0.63)	(1.10)	(1.53)	(0.09)	(1.37)	(0.58)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	48%	80%	74%	91%	36%	90%
	1 yr. % adj.	97%	100%	100%	100%	91%	100%

Note: a description of table contents is included in the first section of table 3E–1.

Table 3E-9: Neighboring country sorghum price transmission ECM model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
Malanville, Benin	$\hat{\gamma}$	-0.26*** (-4.12)	-0.16*** (-2.78)	-0.23*** (-3.84)	-0.22*** (-3.48)	-0.33*** (-3.86)	-0.20*** (-3.06)
	$\hat{\delta}$	0.13 (0.83)	-0.11 (-0.63)	0.13 (0.85)	0.03 (0.28)	-0.04 (-0.42)	0.11 (1.55)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	45%	29%	41%	39%	55%	36%
	1 yr. % adj.	96%	85%	95%	94%	99%	92%
Accra, Ghana	$\hat{\gamma}$	-0.59*** (-4.53)	-0.44*** (-3.92)	-0.63*** (-5.51)	-0.15** (-2.23)	-0.31*** (-2.84)	-0.62*** (-5.13)
	$\hat{\delta}$	0.85** (2.47)	0.88** (2.08)	0.80** (2.42)	0.49*** (2.65)	0.01 (0.07)	0.46*** (3.25)
	1 mo. % adj.	85%	88%	80%	49%	0	46%
	3 mo. % adj.	97%	96%	97%	63%	52%	92%
	1 yr. % adj.	100%	100%	100%	92%	98%	100%
Bolgatanga, Ghana	$\hat{\gamma}$	-0.34*** (-3.81)	-0.51*** (-4.71)	-0.40*** (-3.96)	-0.18*** (-3.40)	-0.37*** (-3.19)	-0.32*** (-3.48)
	$\hat{\delta}$	-0.05 (-0.19)	0.11 (0.34)	0.04 (0.12)	-0.02 (-0.17)	0.11 (0.69)	-0.05 (-0.35)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	57%	76%	65%	33%	60%	54%
	1 yr. % adj.	99%	100%	100%	89%	99%	99%
Lomé, Togo	$\hat{\gamma}$	-0.16*** (-3.33)	-0.15*** (-3.19)	-0.12** (-2.50)	-0.07* (-1.97)	-0.15*** (-3.05)	-0.11*** (-2.29)
	$\hat{\delta}$	0.06 (0.80)	0.01 (0.10)	-0.07 (-1.03)	-0.04 (-0.83)	-0.03 (-0.61)	-0.06 (-1.63)
	1 mo. % adj.	0	0	0	-	0	0
	3 mo. % adj.	29%	27%	23%	-	27%	20%
	1 yr. % adj.	85%	82%	76%	-	83%	71%
Korbongou, Togo	$\hat{\gamma}$	-0.15*** (-3.34)	-0.14*** (-3.43)	-0.15*** (-3.42)	-0.13*** (-3.31)	-0.25*** (-4.38)	-0.18*** (-3.61)
	$\hat{\delta}$	0.04 (0.75)	-0.05 (-1.07)	0.08* (1.83)	0.01 (0.40)	0.07** (2.43)	0.01 (0.52)
	1 mo. % adj.	0	0	0	0	7%	0
	3 mo. % adj.	28%	26%	27%	24%	48%	34%
	1 yr. % adj.	83%	81%	83%	77%	96%	89%
Ouagadougou, Burkina Faso	$\hat{\gamma}$	-0.45*** (-4.55)	-0.43*** (-4.05)	-0.61*** (-5.15)	-0.14*** (-2.86)	-0.39*** (-3.77)	-0.27*** (-2.77)
	$\hat{\delta}$	0.18 (0.55)	0.43 (1.01)	0.41 (1.14)	-0.10 (-0.53)	0.16 (0.82)	0.47*** (2.87)
	1 mo. % adj.	0	0	0	0	0	47%
	3 mo. % adj.	70%	67%	84%	26%	63%	72%
	1 yr. % adj.	100%	100%	100%	81%	100%	98%

Note: a description of table contents is included in the first section of table 3E–1.

cont. Neighboring country sorghum price transmission ECM model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Dori, Burkina Faso	$\hat{\gamma}$	-0.51***	-0.45***	-0.67***	-0.13**	-0.43***	-0.35***
		(-4.86)	(-4.21)	(-5.48)	(-2.38)	(-3.78)	(-3.35)
	$\hat{\delta}$	0.08	0.38	0.59	-0.14	0.41*	0.34
		(0.19)	(0.72)	(1.34)	(-0.61)	(1.84)	(1.59)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	76%	70%	89%	24%	68%	58%
	1 yr. % adj.	100%	100%	100%	78%	100%	99%
Niamey, Niger	$\hat{\gamma}$	-0.36***	-0.23***	-0.24***	-0.20***	-0.37***	-0.35***
		(-5.72)	(-4.24)	(-4.04)	(-3.52)	(-4.75)	(-4.70)
	$\hat{\delta}$	-0.20	0.12	0.18	0.18	0.71***	0.50***
		(-0.94)	(0.50)	(0.80)	(1.11)	(4.89)	(4.48)
	1 mo. % adj.	0	0	0	0	71%	50%
	3 mo. % adj.	60%	41%	43%	35%	88%	79%
	1 yr. % adj.	99%	94%	95%	91%	100%	100%
Maradi, Niger	$\hat{\gamma}$	-0.22***	-0.18***	-0.19***	-0.19***	-0.52***	-0.43***
		(-4.12)	(-3.70)	(-3.72)	(-3.99)	(-7.07)	(-6.59)
	$\hat{\delta}$	-0.03	-0.02	0.08	0.01	0.13	0.05
		(-0.14)	(-0.07)	(0.39)	(0.04)	(1.04)	(0.48)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	38%	33%	34%	34%	77%	67%
	1 yr. % adj.	93%	89%	90%	90%	100%	100%
N'Djamena, Chad	$\hat{\gamma}$	-0.35***	-0.30***	-0.28***	-0.22***	-0.38***	-0.27***
		(-4.96)	(-4.57)	(-3.86)	(-3.83)	(-4.22)	(-3.50)
	$\hat{\delta}$	-0.14	-0.16	0.20	0.07	0.47***	0.30***
		(-0.80)	(-0.75)	(1.08)	(0.54)	(3.61)	(3.24)
	1 mo. % adj.	0	0	0	0	47%	30%
	3 mo. % adj.	57%	51%	49%	39%	80%	62%
	1 yr. % adj.	99%	98%	97%	93%	100%	98%
Moundou, Chad	$\hat{\gamma}$	-0.29***	-0.20***	-0.21***	-0.16***	-0.32***	-0.18***
		(-4.39)	(-3.53)	(-3.41)	(-3.31)	(-4.50)	(-2.90)
	$\hat{\delta}$	-0.14	-0.21	0.07	-0.08	-0.07	0.26***
		(-0.84)	(-1.04)	(0.42)	(-0.65)	(-0.60)	(2.96)
	1 mo. % adj.	0	0	0	0	0	26%
	3 mo. % adj.	49%	36%	38%	30%	53%	51%
	1 yr. % adj.	98%	92%	93%	85%	98%	92%
Bamako, Mali	$\hat{\gamma}$	-0.32***	-0.45***	-0.51***	-0.10**	-0.44***	-0.30***
		(-3.42)	(-4.26)	(-4.48)	(-2.13)	(-4.08)	(-3.02)
	$\hat{\delta}$	0.67**	0.68*	0.68**	-0.03	0.33**	0.22
		(2.13)	(1.83)	(2.04)	(-0.16)	(2.06)	(1.38)
	1 mo. % adj.	67%	0	68%	0	33%	0
	3 mo. % adj.	85%	69%	93%	19%	79%	51%
	1 yr. % adj.	100%	100%	100%	68%	100%	98%
Mopti, Mali	$\hat{\gamma}$	-0.24***	-0.19***	-0.19***	-0.16***	-0.36***	-0.30***
		(-3.57)	(-3.14)	(-2.97)	(-3.02)	(-4.32)	(-4.09)
	$\hat{\delta}$	0.29	0.29	0.47	0.12	0.38	0.53***
		(0.86)	(0.75)	(1.36)	(0.49)	(1.65)	(3.19)
	1 mo. % adj.	0	0	0	0	0	53%
	3 mo. % adj.	42%	34%	34%	29%	59%	77%
	1 yr. % adj.	95%	90%	90%	85%	99%	99%

Note: a description of table contents is included in the first section of table 3E–1.

Table 3E-10: Neighboring country millet price transmission ECM model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Accra, Ghana	$\hat{\gamma}$	-0.49*** (-4.68)	-0.31*** (-3.01)	-0.27*** (-3.03)	-0.24*** (-2.57)	-0.34*** (-3.28)	-0.15** (-2.11)
	$\hat{\delta}$	-0.55*** (-2.70)	0.05 (0.21)	0.35 (1.60)	0.06 (0.34)	0.02 (0.17)	-0.03 (-0.23)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	60%	52%	47%	43%	56%	28%
	1 yr. % adj.	100%	98%	97%	95%	99%	84%
Bolgatanga, Ghana	$\hat{\gamma}$	-0.51*** (-4.16)	-0.25*** (-2.56)	-0.30*** (-2.78)	-0.13 (-1.33)	-0.31*** (-3.34)	-0.16** (-1.33)
	$\hat{\delta}$	0.05 (0.18)	0.03 (0.11)	0.10 (0.42)	-0.17 (-0.83)	0.02 (0.20)	-0.02 (-0.16)
	1 mo. % adj.	0	0	0	-	0	0
	3 mo. % adj.	76%	43%	51%	-	52%	29%
	1 yr. % adj.	100%	96%	98%	-	98%	85%
Ouagadougou, Burkina Faso	$\hat{\gamma}$	-0.57*** (-4.23)	-0.27*** (-2.74)	-0.29*** (-2.87)	-0.35*** (-3.26)	-0.51*** (-4.12)	-0.13 (-1.49)
	$\hat{\delta}$	0.20 (0.41)	-0.33 (-0.69)	0.57 (1.27)	-0.10 (-0.29)	0.28 (1.59)	-0.07 (-0.42)
	1 mo. % adj.	0	0	0	0	0	-
	3 mo. % adj.	82%	46%	49%	58%	76%	-
	1 yr. % adj.	100%	97%	98%	99%	100%	-
Dori, Burkina Faso	$\hat{\gamma}$	-0.63*** (-4.64)	-0.25** (-2.54)	-0.28*** (-2.82)	-0.29** (-2.78)	-0.48*** (-4.16)	-0.16* (-1.71)
	$\hat{\delta}$	0.74 (1.55)	0.28 (0.54)	0.17 (0.36)	-0.23 (-0.66)	0.10 (0.53)	0.06 (0.22)
	1 mo. % adj.	0	0	0	0	0	-
	3 mo. % adj.	86%	44%	48%	49%	73%	-
	1 yr. % adj.	100%	96%	97%	98%	100%	-
Niamey, Niger	$\hat{\gamma}$	-0.39*** (-5.53)	-0.14*** (-3.06)	-0.09** (-2.02)	-0.31*** (-5.05)	-0.34*** (-4.84)	-0.28*** (-4.38)
	$\hat{\delta}$	0.14 (0.67)	0.14 (0.78)	0.12 (0.55)	0.16 (1.13)	0.41*** (3.59)	0.32*** (2.65)
	1 mo. % adj.	0	0	0	0	41%	32%
	3 mo. % adj.	63%	26%	18%	52%	74%	65%
	1 yr. % adj.	100%	80%	66%	98%	99%	98%

Note: a description of table contents is included in the first section of table 3E–1.

cont. Neighboring country millet price transmission ECM model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Maradi, Niger	$\hat{\gamma}$	-0.28*** (-4.69)	-0.13*** (-3.07)	-0.08* (-1.93)	-0.24*** (-4.62)	-0.43*** (-6.61)	-0.22*** (-4.29)
	$\hat{\delta}$	-0.10 (-0.53)	-0.09 (-0.56)	-0.06 (-0.32)	0.13 (0.94)	0.18* (1.80)	0.24** (2.22)
	1 mo. % adj.	0	0	-	0	0	24%
	3 mo. % adj.	48%	23%	-	42%	67%	54%
	1 yr. % adj.	97%	77%	-	95%	100%	95%
N'Djamena, Chad	$\hat{\gamma}$	-0.43*** (-4.73)	-0.15*** (-2.76)	-0.11* (-1.85)	-0.26*** (-3.77)	-0.38*** (-4.76)	-0.33*** (-4.47)
	$\hat{\delta}$	0.13 (0.69)	-0.30* (1.70)	0.23 (1.17)	0.06 (0.49)	0.12 (1.21)	0.13 (1.31)
	1 mo. % adj.	0	0	-	0	0	0
	3 mo. % adj.	68%	28%	-	45%	62%	55%
	1 yr. % adj.	100%	83%	-	96%	100%	99%
Moundou, Chad	$\hat{\gamma}$	-0.41*** (-4.74)	-0.14** (-2.58)	-0.10* (-1.71)	-0.20*** (-3.10)	-0.38*** (-4.45)	-0.36*** (-4.68)
	$\hat{\delta}$	-0.12 (-0.55)	-0.26 (-1.24)	0.25 (1.08)	0.05 (0.31)	0.20* (1.72)	0.19* (1.75)
	1 mo. % adj.	0	0	-	0	0	0
	3 mo. % adj.	61%	26%	-	36%	62%	59%
	1 yr. % adj.	100%	81%	-	91%	100%	99%
Bamako, Mali	$\hat{\gamma}$	-0.33*** (-3.64)	-0.19** (-2.68)	-0.18** (-2.63)	-0.20*** (-2.76)	-0.43*** (-4.14)	-0.20*** (-2.75)
	$\hat{\delta}$	0.33 (1.49)	0.20 (0.92)	-0.04 (-0.16)	0.29* (1.74)	0.38*** (2.97)	0.16 (1.21)
	1 mo. % adj.	0	0	0	0	38%	0
	3 mo. % adj.	70%	35%	32%	36%	80%	36%
	1 yr. % adj.	99%	91%	88%	91%	100%	91%
Mopti, Mali	$\hat{\gamma}$	-0.34*** (-4.11)	-0.12** (-2.31)	-0.06 (-1.22)	-0.19*** (-2.94)	-0.26*** (-3.61)	-0.19*** (-3.03)
	$\hat{\delta}$	0.44 (1.02)	0.15 (0.40)	0.54 (1.32)	0.43 (1.51)	0.84*** (3.98)	0.47** (2.10)
	1 mo. % adj.	0	0	-	0	84%	47%
	3 mo. % adj.	57%	22%	-	34%	91%	65%
	1 yr. % adj.	99%	75%	-	90%	99%	94%

Note: a description of table contents is included in the first section of table 3E–1.

Table 3E-11: Neighboring country cassava price transmission ECM model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Cotonou, Benin	$\hat{\gamma}$	-0.25*** (-4.03)	-0.55*** (-6.76)	-0.27*** (-3.83)	-0.17*** (-3.19)	-0.18*** (-3.43)	-0.26*** (-3.70)
	$\hat{\delta}$	0.27* (1.96)	0.04 (0.21)	0.25 (1.41)	0.17 (1.45)	0.15 (1.31)	0.28* (1.98)
	1 mo. % adj.	0	0	0	0	0	28%
	3 mo. % adj.	59%	80%	47%	31%	33%	60%
	1 yr. % adj.	97%	100%	97%	87%	89%	97%
Malanville, Benin	$\hat{\gamma}$	-0.27*** (-3.87)	-0.61*** (-6.52)	-0.32*** (-3.99)	-0.24*** (-3.32)	-0.38*** (-4.95)	-0.38*** (-4.53)
	$\hat{\delta}$	0.23 (1.37)	0.07 (0.30)	0.40* (1.90)	0.26* (1.92)	0.33** (2.38)	0.39** (2.14)
	1 mo. % adj.	0	0	0	0	33%	39%
	3 mo. % adj.	47%	85%	54%	43%	74%	77%
	1 yr. % adj.	97%	100%	99%	95%	100%	100%
Accra, Ghana	$\hat{\gamma}$	-0.31*** (-3.20)	-0.78*** (-5.87)	-0.38*** (-3.65)	-0.26*** (-2.95)	-0.15** (-2.40)	-0.32** (-3.34)
	$\hat{\delta}$	-0.24 (-0.47)	0.94 (1.40)	-0.59 (-0.89)	0.48 (1.25)	-0.12 (-0.32)	-0.38 (-0.80)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	52%	95%	61%	46%	28%	54%
	1 yr. % adj.	98%	100%	99%	97%	83%	99%
Lomé, Togo	$\hat{\gamma}$	-0.31*** (-4.80)	-0.52*** (-6.71)	-0.38*** (-4.69)	-0.26*** (-4.10)	-0.37*** (-5.34)	-0.41*** (-5.35)
	$\hat{\delta}$	0.06 (0.60)	0.05 (0.42)	0.03 (0.25)	0.11* (1.32)	0.18** (2.28)	0.02 (0.27)
	1 mo. % adj.	0	0	0	0	18%	0
	3 mo. % adj.	53%	77%	61%	45%	68%	65%
	1 yr. % adj.	98%	100%	99%	96%	100%	100%
Korbongou, Togo	$\hat{\gamma}$	-0.29*** (-4.31)	-0.64*** (-7.36)	-0.26*** (-3.60)	-0.14*** (-2.90)	-0.13** (-2.83)	-0.27*** (-3.80)
	$\hat{\delta}$	0.20 (1.56)	0.37** (2.15)	0.11 (0.68)	-0.06 (-0.59)	0.08 (0.70)	0.01 (0.08)
	1 mo. % adj.	0	37%	0	0	0	0
	3 mo. % adj.	49%	92%	45%	26%	25%	46%
	1 yr. % adj.	98%	100%	96%	81%	79%	97%
Yaoundé, Cameroon	$\hat{\gamma}$	-0.30*** (-3.42)	-0.73*** (-6.31)	-0.30*** (-3.03)	-0.19** (-2.72)	-0.12** (-2.26)	-0.29*** (-3.25)
	$\hat{\delta}$	0.61 (0.92)	0.59 (0.65)	0.52 (0.57)	0.02 (0.04)	0.49 (1.03)	0.25 (0.38)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	51%	93%	51%	34%	23%	49%
	1 yr. % adj.	98%	100%	98%	90%	76%	98%

Note: a description of table contents is included in the first section of table 3E–1.

Table 3E-12: Neighboring country yam and cowpea price transmission ECM model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
Yams							
Accra, Ghana	$\hat{\gamma}$	-0.58*** (-5.02)	-0.51*** (-4.37)	-0.34*** (-3.20)	-0.25*** (-3.23)	-0.68*** (-5.44)	-0.34*** (-3.49)
	$\hat{\delta}$	-0.09 (-0.42)	0.17 (0.99)	0.30 (1.38)	0.18 (1.27)	-0.27 (-1.09)	0.16 (0.93)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	82%	76%	57%	44%	90%	56%
	1 yr. % adj.	100%	100%	99%	96%	100%	99%
Bolgatanga, Ghana	$\hat{\gamma}$	-0.58*** (-4.94)	-0.51*** (-4.30)	-0.35*** (-2.73)	-0.26*** (-3.29)	-0.62*** (-4.26)	-0.28*** (-2.75)
	$\hat{\delta}$	-0.42* (-1.85)	0.05 (0.27)	0.36 (1.60)	0.12 (0.89)	-0.08 (-0.29)	0.17 (0.93)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	82%	77%	57%	46%	85%	48%
	1 yr. % adj.	100%	100%	100%	97%	100%	97%
Cowpea							
Garoua, Cameroon	$\hat{\gamma}$	-0.07 (-1.59)	-0.38*** (-4.18)	-0.16** (-2.58)	-0.04 (-0.93)	-0.12** (-2.13)	-0.09* (-1.75)
	$\hat{\delta}$	0.06 (0.71)	0.08 (0.58)	-0.05 (-0.35)	-0.01 (-0.17)	0.34** (2.48)	0.01 (0.12)
	1 mo. % adj.	-	0	0	-	34%	-
	3 mo. % adj.	-	61%	29%	-	49%	-
	1 yr. % adj.	-	99%	85%	-	85%	-
Cotonou, Benin	$\hat{\gamma}$	-0.28*** (-3.05)	-0.53*** (-3.90)	-0.17* (-1.84)	-0.13** (-2.03)	-0.31*** (-2.85)	-0.35*** (-3.12)
	$\hat{\delta}$	-0.01 (-0.09)	0.01 (0.04)	0.18* (1.87)	-0.03 (-0.41)	0.01 (0.03)	0.15 (1.43)
	1 mo. % adj.	0	0	-	0	0	0
	3 mo. % adj.	48%	78%	-	25%	52%	58%
	1 yr. % adj.	97%	100%	-	79%	98%	99%
Niamey, Niger	$\hat{\gamma}$	-0.19*** (-3.84)	-0.30*** (-5.05)	-0.24*** (-3.85)	-0.16*** (-3.39)	-0.29*** (-4.67)	-0.22*** (-3.90)
	$\hat{\delta}$	-0.00 (-0.04)	-0.21 (-1.54)	0.06 (0.38)	0.02 (0.24)	0.08 (0.58)	0.16* (1.67)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	34%	51%	42%	30%	50%	39%
	1 yr. % adj.	90%	98%	95%	95%	98%	93%
Maradi, Niger	$\hat{\gamma}$	-0.16*** (-3.01)	-0.25*** (-3.63)	-0.20*** (-3.05)	-0.10** (-2.05)	-0.24*** (-3.35)	-0.18*** (-3.03)
	$\hat{\delta}$	-0.03 (-0.26)	-0.05 (-0.26)	0.09 (0.49)	0.05 (0.48)	0.06 (0.33)	0.19 (1.60)
	1 mo. % adj.	0	0	0	0	0	0
	3 mo. % adj.	29%	43%	37%	19%	42%	33%
	1 yr. % adj.	84%	96%	92%	68%	95%	89%

Note: a description of table contents is included in the first section of table 3E–1.

Table 3E-13: Commercial hub-to-urban market maize, millet, and sorghum price transmission ECM model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
Maize							
Hub: Kano	$\hat{\gamma}$	-0.20*** (-3.71)	-0.33*** (-4.58)	-0.14*** (-2.80)	-0.29*** (-4.79)	…	-0.55*** (-6.74)
	$\hat{\delta}$	0.39*** (3.25)	0.16 (0.82)	0.18 (1.32)	0.44*** (4.76)	…	0.47*** (4.66)
	1 mo. % adj.	39%	0	0	44%	…	47%
	3 mo. % adj.	61%	55%	25%	72%	…	89%
	1 yr. % adj.	95%	99%	80%	99%	…	100%
Millet							
Hub: Kano	$\hat{\gamma}$	-0.24*** (-4.32)	-0.11*** (-2.66)	-0.06 (-1.46)	-0.21*** (-3.89)	…	-0.17*** (-3.36)
	$\hat{\delta}$	0.34** (2.21)	-0.08 (-0.61)	0.29* (1.86)	0.51*** (5.01)	…	0.58*** (7.70)
	1 mo. % adj.	34%	0	-	51%	…	58%
	3 mo. % adj.	62%	21%	-	70%	…	71%
	1 yr. % adj.	97%	72%	-	96%	…	94%
Sorghum							
Hub: Kano	$\hat{\gamma}$	-0.22*** (-4.43)	-0.13*** (-2.88)	-0.17*** (-3.22)	-0.20*** (-3.75)	…	-0.44*** (-5.03)
	$\hat{\delta}$	-0.03 (-0.17)	0.26* (1.78)	0.22 (1.47)	0.51*** (5.84)	…	0.30*** (4.02)
	1 mo. % adj.	0	0	0	51%	…	30%
	3 mo. % adj.	39%	24%	31%	69%	…	78%
	1 yr. % adj.	94%	78%	87%	96%	…	100%

Note: a description of table contents is included in the first section of table 3E–1.

Table 3E-14: Commercial hub-to-urban market cassava, yams, and cowpea price transmission ECM model estimation results

Price series		**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
				Cassava			
Hub 1: Lagos	$\hat{\gamma}$	…	-0.66*** (-7.57)	-0.49*** (-5.75)	-0.28*** (-4.50)	-0.24*** (-3.94)	-0.52*** (-5.82)
	$\hat{\delta}$	…	0.59*** (5.52)	0.35*** (3.39)	0.17** (2.33)	0.18** (2.35)	0.41*** (5.10)
	1 mo. % adj.	…	59%	35%	17%	18%	41%
	3 mo. % adj.	…	95%	83%	57%	52%	86%
	1 yr. % adj.	…	100%	100%	98%	96%	100%
Hub 2: Kano	$\hat{\gamma}$	-0.38*** (-5.24)	-0.54*** (-6.72)	-0.51*** (-5.90)	-0.11* (-1.76)	…	-0.48*** (-5.77)
	$\hat{\delta}$	0.25** (2.44)	0.23 (1.65)	0.38*** (3.01)	0.37*** (4.22)	…	0.26** (2.60)
	1 mo. % adj.	25%	23%	38%	-	…	26%
	3 mo. % adj.	72%	78%	85%	-	…	80%
	1 yr. % adj.	100%	100%	100%	-	…	100%
				Yams			
Hub 1: FCT (Abuja)	$\hat{\gamma}$	-0.40*** (-5.33)	-0.53*** (-6.84)	-0.35*** (-4.87)	…	-0.38*** (-4.99)	-0.58*** (-6.58)
	$\hat{\delta}$	0.41*** (3.42)	0.24*** (2.68)	0.42*** (3.90)	…	0.16 (1.31)	0.21** (2.13)
	1 mo. % adj.	41%	24%	42%	…	0	21%
	3 mo. % adj.	78%	83%	75%	…	62%	86%
	1 yr. % adj.	100%	100%	99%	…	100%	100%
Hub 2: Kano	$\hat{\gamma}$	-0.47*** (-5.65)	-0.50*** (-5.99)	-0.22*** (-3.07)	-0.24*** (-3.77)	…	-0.31*** (-4.14)
	$\hat{\delta}$	0.37*** (4.60)	0.05 (0.74)	-0.04 (-0.51)	0.08 (1.19)	…	0.08 (1.18)
	1 mo. % adj.	37%	0	0	0	…	0
	3 mo. % adj.	82%	75%	40%	42%	…	52%
	1 yr. % adj.	100%	100%	94%	95%	…	98%
				Cowpea			
Hub: Kano	$\hat{\gamma}$	-0.32*** (-4.62)	-0.27*** (-4.59)	-0.29*** (-5.01)	-0.23*** (-3.45)	…	-0.47*** (-5.69)
	$\hat{\delta}$	0.31*** (5.29)	0.13 (1.52)	0.18** (2.12)	0.22*** (4.04)	…	0.28*** (4.45)
	1 mo. % adj.	31%	0	18%	22%	…	28%
	3 mo. % adj.	68%	47%	59%	54%	…	80%
	1 yr. % adj.	99%	97%	98%	96%	…	100%

Note: a description of table contents is included in the first section of table 3E–1.

Table 3E-15: Commercial hub-to-urban market local rice price transmission ECM model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Hub 1: Kano	$\hat{\gamma}$	-0.37*** (-5.17)	-0.66*** (-7.12)	-0.33*** (-4.53)	-0.45*** (-5.39)	…	-0.48*** (-5.65)
	$\hat{\delta}$	0.75*** (5.45)	**1.11***** (4.40)	0.17 (1.38)	0.81*** (5.30)	…	0.58*** (4.50)
	1 mo. % adj.	75%	111%	0	81%	…	58%
	3 mo. % adj.	90%	101%	55%	94%	…	89%
	1 yr. % adj.	100%	100%	99%	100%	…	100%
Hub 2: FCT (Abuja)	$\hat{\gamma}$	-0.25*** (-4.05)	-0.69*** (-7.79)	-0.36*** (-5.26)	…	-0.20*** (-3.29)	-0.51*** (-6.22)
	$\hat{\delta}$	0.24*** (3.03)	0.55*** (4.78)	0.25*** (3.86)	…	0.26*** (5.42)	0.26*** (3.52)
	1 mo. % adj.	24%	55%	25%	…	26%	26%
	3 mo. % adj.	57%	96%	70%	…	53%	82%
	1 yr. % adj.	97%	100%	99%	…	94%	100%
Hub 3: Enugu	$\hat{\gamma}$	-0.31*** (-4.78)	-0.67*** (-7.56)	…	-0.61*** (-7.03)	-0.29*** (-4.35)	-0.46*** (-6.10)
	$\hat{\delta}$	0.02 (0.19)	0.65*** (3.99)	…	0.44*** (3.90)	0.10 (1.34)	0.17* (1.73)
	1 mo. % adj.	0	65%	…	44%	0	0
	3 mo. % adj.	53%	96%	…	91%	50%	71%
	1 yr. % adj.	98%	100%	…	100%	98%	100%

Note: a description of table contents is included in the first section of table 3E–1.

Table 3E-16: Commercial hub-to-urban market imported rice price transmission ECM model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Hub 1: Lagos	$\hat{\gamma}$	…	-0.37*** (-5.34)	-0.47*** (-5.73)	-0.47*** (-6.09)	-0.46*** (-5.43)	-0.44*** (-5.74)
	$\hat{\delta}$	…	0.45*** (4.53)	0.57*** (5.98)	0.44*** (6.68)	0.45*** (5.90)	0.48*** (6.67)
	1 mo. % adj.	…	45%	57%	44%	45%	48%
	3 mo. % adj.	…	78%	87%	84%	84%	84%
	1 yr. % adj.	…	100%	100%	100%	100%	100%
Hub 2: Rivers	$\hat{\gamma}$	-0.29*** (-4.00)	…	-0.28*** (-4.00)	-0.19*** (-3.14)	-0.17*** (-2.99)	-0.33*** (-4.48)
	$\hat{\delta}$	0.34*** (4.76)	…	0.46*** (6.17)	0.24*** (4.25)	0.37*** (7.03)	0.35*** (5.48)
	1 mo. % adj.	34%	…	46%	24%	37%	35%
	3 mo. % adj.	67%	…	72%	50%	57%	71%
	1 yr. % adj.	99%	…	98%	92%	92%	99%
Hub 3: Enugu	$\hat{\gamma}$	-0.54*** (-6.87)	-0.36*** (-4.97)	…	-0.44*** (-6.42)	-0.42*** (-5.41)	-0.39*** (-5.23)
	$\hat{\delta}$	0.39*** (5.91)	0.51*** (6.01)	…	0.32*** (5.67)	0.44*** (6.68)	0.47*** (7.64)
	1 mo. % adj.	39%	51%	…	32%	44%	47%
	3 mo. % adj.	87%	80%	…	79%	81%	80%
	1 yr. % adj.	100%	100%	…	100%	100%	100%
Hub 4: Kano	$\hat{\gamma}$	-0.73*** (-7.75)	-0.30*** (-3.93)	-0.47*** (-5.48)	-0.53*** (-6.25)	…	-0.48*** (-5.38)
	$\hat{\delta}$	0.54*** (5.83)	0.84*** (6.86)	0.66*** (6.70)	0.51*** (6.49)	…	0.43*** (4.51)
	1 mo. % adj.	54%	84%	66%	51%	…	43%
	3 mo. % adj.	97%	92%	90%	89%	…	85%
	1 yr. % adj.	100%	100%	100%	100%	…	100%

Note: a description of table contents is included in the first section of table 3E–1.

Table 3E-17: Commercial hub-to-urban market imported rice to local rice price transmission ECM model estimation results

Price series		Lagos	Rivers	Enugu	FCT (Abuja)	Kano	Borno
Hub 1: Lagos	$\hat{\gamma}$	…	-0.64*** (-7.64)	-0.32*** (-4.88)	-0.58*** (-7.24)	-0.27*** (-3.97)	-0.49*** (-5.90)
	$\hat{\delta}$	…	0.23* (1.89)	-0.01 (-0.10)	0.34*** (4.30)	0.15*** (3.09)	0.26*** (3.44)
	1 mo. % adj.	…	0	0	34%	15%	26%
	3 mo. % adj.	…	87%	53%	88%	54%	81%
	1 yr. % adj.	…	100%	98%	100%	97%	100%
Hub 2: Rivers	$\hat{\gamma}$	-0.24*** (-3.80)	…	-0.31*** (-4.96)	-0.49*** (-5.95)	-0.16*** (-2.67)	-0.41*** (-5.10)
	$\hat{\delta}$	0.27*** (4.27)	…	0.09* (1.77)	0.30*** (4.35)	0.10*** (2.67)	0.23*** (3.80)
	1 mo. % adj.	27%	…	0	30%	0	23%
	3 mo. % adj.	58%	…	52%	82%	37%	73%
	1 yr. % adj.	96%	…	98%	100%	87%	100%
Hub 3: Enugu	$\hat{\gamma}$	-0.37*** (-4.95)	-0.67*** (-7.70)	…	-0.64*** (-7.95)	-0.29*** (-4.68)	-0.44*** (-5.90)
	$\hat{\delta}$	0.31*** (4.59)	0.41*** (3.98)	…	0.30*** (4.53)	0.15*** (3.52)	0.27*** (4.49)
	1 mo. % adj.	31%	41%	…	30%	15%	27%
	3 mo. % adj.	73%	93%	…	91%	58%	77%
	1 yr. % adj.	100%	100%	…	100%	98%	100%
Hub 4: Kano	$\hat{\gamma}$	-0.60*** (-6.68)	-0.70*** (-7.45)	-0.38*** (-5.06)	-0.51*** (-5.90)	…	-0.54*** (-5.91)
	$\hat{\delta}$	0.45*** (5.26)	0.66*** (4.47)	0.12 (1.63)	0.42*** (4.57)	…	0.33*** (4.19)
	1 mo. % adj.	45%	66%	0	42%	…	33%
	3 mo. % adj.	91%	97%	61%	86%	…	86%
	1 yr. % adj.	100%	100%	99%	100%	…	100%

Note: a description of table contents is included in the first section of table 3E–1.

Table 3E-18: Urban-to-rural market maize, millet, sorghum, and cowpea price transmission ECM model estimation results

Price series	**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
			Maize			
$\hat{\gamma}$	-0.16* (-1.94)	-0.38*** (-3.14)	-0.64*** (-4.89)	-0.30*** (-2.82)	-0.68*** (-4.44)	-0.57*** (-4.22)
$\hat{\delta}$	0.36*** (3.07)	0.32** (2.38)	0.38*** (3.15)	0.43** (2.44)	0.59*** (3.91)	0.35*** (2.53)
1 mo. % adj.	-	32%	38%	43%	59%	35%
3 mo. % adj.	-	73%	92%	72%	96%	88%
1 yr. % adj.	-	100%	100%	99%	100%	100%
			Millet			
$\hat{\gamma}$	-0.45*** (-2.78)	-0.25** (-2.02)	-0.24** (-1.69)	-0.31** (-2.91)	-0.43*** (-2.92)	-0.29*** (-2.17)
$\hat{\delta}$	0.65** (2.71)	-0.15 (-1.20)	-0.07 (-0.65)	-0.01 (-0.06)	0.38** (2.03)	0.04 (0.29)
1 mo. % adj.	65%	-	-	0	38%	0
3 mo. % adj.	90%	-	-	53%	80%	50%
1 yr. % adj.	100%	-	-	98%	100%	98%
			Sorghum			
$\hat{\gamma}$	-0.35*** (-3.15)	-0.24** (-2.13)	-1.18*** (-8.31)	-0.44*** (-3.46)	-0.38*** (-2.79)	-0.76*** (-5.36)
$\hat{\delta}$	0.46*** (2.74)	0.20 (1.15)	0.54*** (3.42)	0.80*** (4.95)	0.28** (2.24)	0.28 (1.48)
1 mo. % adj.	46%	0	54%	80%	28%	0
3 mo. % adj.	77%	42%	99%	94%	72%	94%
1 yr. % adj.	100%	95%	100%	100%	100%	100%
			Cowpea			
$\hat{\gamma}$	-0.20 (-1.47)	-0.50*** (-3.69)	-0.81*** (-3.70)	-0.16 (-1.16)	-0.47*** (-3.25)	-0.89*** (-6.40)
$\hat{\delta}$	0.38 (1.63)	0.19 (1.35)	0.09 (0.35)	0.20 (1.03)	0.14 (1.13)	0.55*** (4.68)
1 mo. % adj.	-	0	0	-	0	55%
3 mo. % adj.	-	75%	96%	-	72%	99%
1 yr. % adj.	-	100%	100%	-	100%	100%

Source: Nigerian National Bureau of Statistics.
Note: a description of table contents is included in the first section of table 3E–1.

Table 3E-19: Urban-to-rural market cassava, yams, local rice, imported price, and imported rice-to-local rice price transmission ECM model estimation results

Price series	**Lagos**	**Rivers**	**Enugu**	**FCT (Abuja)**	**Kano**	**Borno**
			Cassava			
$\hat{\gamma}$	-0.38***	-0.26***	-0.77***	-0.21**	-0.65***	-0.57***
	(-2.86)	(-2.63)	(-5.04)	(-2.02)	(-4.84)	(-4.25)
$\hat{\delta}$	0.54***	0.04	0.19*	0.22	0.38***	0.23**
	(4.31)	(0.42)	(1.91)	(1.57)	(3.00)	(1.98)
1 mo. % adj.	54%	0	0	0	0	0
3 mo. % adj.	82%	48%	95%	38%	38%	81%
1 yr. % adj.	100%	97%	100%	93%	100%	100%
			Yams			
$\hat{\gamma}$	-0.54***	-0.71***	-0.34***	-0.48***	-0.55***	-0.73***
	(-3.76)	(-4.91)	(-2.45)	(-3.64)	(-3.13)	(-4.94)
$\hat{\delta}$	0.34**	0.10	0.18	0.50**	0.04	0.27
	(2.49)	(1.20)	(1.45)	(2.37)	(0.24)	(1.22)
1 mo. % adj.	34%	0	0	50%	0	0
3 mo. % adj.	86%	92%	57%	86%	80%	93%
1 yr. % adj.	100%	100%	99%	100%	100%	100%
			Local Rice			
$\hat{\gamma}$	-0.49***	-0.57***	-0.90***	-0.23**	-0.87***	-0.53***
	(-3.38)	(-4.10)	(-6.13)	(-2.45)	(-4.13)	(-4.11)
$\hat{\delta}$	0.16	0.50***	0.49***	0.05	0.91***	0.39***
	(1.35)	(5.04)	(4.18)	(0.68)	(4.08)	(3.29)
1 mo. % adj.	0	50%	49%	0	91%	39%
3 mo. % adj.	74%	91%	99%	41%	100%	87%
1 yr. % adj.	100%	100%	100%	95%	100%	100%
			Imported Rice			
$\hat{\gamma}$	-0.73***	-0.65***	-0.35***	-0.20**	-0.60***	-0.54***
	(-4.89)	(-4.70)	(-3.21)	(-2.25)	(-4.14)	(-3.95)
$\hat{\delta}$	0.42***	0.92***	0.23**	0.04	-0.03	0.18
	(2.96)	(8.76)	(2.24)	(0.29)	(-0.17)	(1.26)
1 mo. % adj.	42%	92%	23%	0	0	0
3 mo. % adj.	96%	99%	68%	36%	84%	79%
1 yr. % adj.	100%	100%	99%	91%	100%	100%
			Imported Rice to Local Rice			
$\hat{\gamma}$	-0.49***	-0.62***	-0.90***	-0.37***	-0.57***	-0.55***
	(-3.38)	(-4.64)	(-6.06)	(-3.15)	(-3.17)	(-4.31)
$\hat{\delta}$	0.13	0.09	0.28***	0.07	0.19*	0.20*
	(0.94)	(0.63)	(3.68)	(0.58)	(1.69)	(1.76)
1 mo. % adj.	0	0	28%	0	0	0
3 mo. % adj.	74%	87%	99%	60%	81%	80%
1 yr. % adj.	100%	100%	100%	99%	100%	100%

Source: Nigerian National Bureau of Statistics.

Note: a description of table contents is included in the first section of table 3E–1.

Appendix 4A. List of Prices Used in the Urban Price Model Set and Summary Statistics for Katsina State and the Prices Used in the Local Model Set

Table 4A-1: World and neighboring country price series that were external prices in the urban price analysis

	Kano State	*Katsina State*	*Borno State*
Maize	Maradi, Niger	Maradi, Niger	Maradi, Niger
Millet	Ouagadougou, Burkina Faso	Ouagadougou, Burkina Faso	Moundou, Chad
Sorghum	Niamey, Niger	Niamey, Niger	Niamey, Niger
Imported rice	Niamey, Niger	Niamey, Niger	World Bank (Thai 25% broken)
Local rice	World Bank (Thai 25% broken)	Niamey, Niger	World Bank (Thai 25% broken)
Cassava	Malanville, Benin	Malanville, Benin	Bangkok, Thailand
Yams	Accra, Ghana	Bolgatanga, Ghana	Accra, Ghana
Cowpeas	Niamey, Niger	Niamey, Niger	Cotonou, Benin

Note: the summary statistics for each series are in Chapter 3, Appendix 3B.

Table 4A-2: Katsina State urban and rural price summary statistics

Crop	***n***	**Mean**	**SD**	**CV**	**ADF**	**PP**	**ADF Δ**	**PP Δ**
				Katsina State urban prices				
Maize	*120*	40.82	14.29	0.35	-2.60*	-2.52	-13.26***	-13.22***
Millet	*108*	39.13	12.76	0.33	-2.14	-2.81*	-10.58***	-12.52***
Sorghum	*120*	39.17	15.38	0.39	-2.49	-2.35	-4.66***	-13.51***
Imported rice	*120*	104.50	36.35	0.35	-1.54	-1.63	-15.69***	-16.46***
Local rice	*120*	74.39	24.18	0.33	-1.67	-1.76	-7.00***	-15.47***
Cassava	*120*	69.14	19.51	0.28	-0.96	-0.73	-12.31***	-12.35***
Yams	*120*	84.91	31.34	0.37	-1.49	-2.65*	-9.83***	-20.29***
Cowpeas	*120*	84.96	38.16	0.45	-1.53	-1.65	-14.83***	-15.25***
				Katsina State rural prices				
Maize	*48*	48.06	9.88	0.21	-2.45	-2.26	-9.33***	-9.72***
Millet	*48*	48.20	10.12	0.21	-2.41	-2.32	-1.33	-8.41***
Sorghum	*48*	45.11	8.73	0.19	-2.84*	-2.65*	-6.46***	-8.28***
Imported rice	*48*	147.47	22.84	0.15	-3.22**	-1.84	-8.08***	-8.06***
Local rice	*48*	101.50	18.97	0.19	-1.63	-1.84	-9.42***	-9.17***
Cassava	*48*	80.23	16.76	0.21	-0.46	-1.32	-13.28***	-14.49***
Yams	*48*	81.88	16.88	0.21	-5.15***	-5.31***	-8.15***	-13.07***
Cowpeas	*48*	97.80	30.93	0.32	-2.18	-2.14	-8.28***	-8.23***

Note: Summary statistics for Kano and Borno states prices are in Chapter 3, Appendix 3B. Units for mean and standard deviation (SD) are Naira/kilogram. CV is the coefficient of variation, which is the SD divided by the mean. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Critical values for ADF and PP statistics for n=100 are -3.50, -2.90, and -2.59, and for n=50 are -3.59, -2.93, and -2.60, respectively. Δ is the first difference ($p_t - p_{t-1}$). ADF and PP statistics for the first difference of each series have the critical values for n=100 are -2.60, -1.95, and -1.61, and for n=50 are -2.62, -1.95, and -1.60, respectively. All critical values are provided in Fuller (1996).

Table 4A-3: Local price summary statistics for the period January 2007 to December 2010

Crop	***n***	**Mean**	**SD**	**CV**	**ADF**	**PP**	**ADF Δ**	**PP Δ**
				Damasak, Borno				
Maize	*32*	51.82	7.57	0.15	-3.55**	-3.28**	-3.84***	-4.83***
Millet	*32*	49.66	7.47	0.15	-2.97**	-3.35**	-5.89***	-5.97***
Sorghum	*31*	43.86	5.92	0.13	-3.41**	-3.37**	-5.07***	-5.08***
Imported rice	*32*	135.33	20.00	0.15	-1.36	-2.51	-4.45***	-5.35***
				Daura, Katsina				
Maize	*36*	49.32	11.27	0.23	-1.88	-1.87	-5.33***	-4.43***
Millet	*36*	46.69	8.48	0.18	-2.07	-2.09	-4.78***	-4.75***
Sorghum	*36*	45.67	10.43	0.23	-1.99	-1.98	-1.40	-4.46***
Imported rice	*36*	127.06	24.23	0.19	-1.87	-1.82	-5.30***	-5.30***
				Jibia, Katsina				
Maize	*32*	48.96	10.70	0.22	-3.15**	-3.02**	-4.68***	-4.18***
Millet	*32*	48.35	8.14	0.17	-3.07**	-3.07**	-4.92***	-4.84***
Sorghum	*32*	45.24	8.22	0.18	-2.81*	-2.49	-3.37***	-3.92***
Imported rice	*32*	139.78	22.03	0.16	-0.86	-3.19**	-5.14***	-6.00***

Note: a discussion of table contents is included below table 4A-2.

Appendix 4B. Comprehensive Results for the Urban Price Model Set

Levels models

	Base	with Northern Nigeria interactions	with Borno State interactions	with both interactions
Intercept	11.05*** (4.88)	11.35*** (5.01)	11.06*** (4.72)	11.44*** (4.92)
Maradi, Niger price	0.75*** (15.77)	0.74*** (15.15)	0.76*** (15.15)	0.74*** (14.58)
LS x Northern Nigeria downward NDVI anomaly	…	0.05 (0.77)	…	0.08 (0.89)
LS x Northern Nigeria upward NDVI anomaly	…	0.10 (1.54)	…	0.21** (2.32)
LS x Borno State downward NDVI anomaly	…	…	-0.00 (-0.01)	-0.04 (-0.53)
LS x Borno State upward NDVI anomaly	…	…	-0.01 (-0.16)	-0.15* (-1.77)
ADF	-4.91***	-4.71***	-4.94***	-4.79***
PP	-5.73***	-5.69***	-5.73***	-5.83***
Adj. R^2	0.70	0.70	0.69	0.70

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.50*** (-6.04)	-0.50*** (-5.99)	-0.51*** (-6.11)	-0.52*** (-5.90)	-0.50*** (-5.91)	-0.50*** (-6.01)	-0.50*** (-6.00)
Maradi, Niger price first difference	0.53*** (3.74)	0.53*** (3.67)	0.57*** (3.96)	0.53*** (3.75)	0.53*** (3.57)	0.53*** (3.70)	0.53*** (3.68)
Northern Nigeria downward NDVI anomaly	…	2.16 (0.66)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	-1.56 (-0.48)	…	…	…	…	…
Borno State downward NDVI anomaly	…	…	-1.92 (-0.84)	…	…	…	…
Borno State upward NDVI anomaly	…	…	-3.52 (-1.45)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	-4.33 (-0.46)	…	…	…
Borno State NDVI first difference	…	…	…	…	0.12 (0.01)	…	…
Nigerian national prod. first difference	…	...	…	…	…	-0.00 (-0.15)	…
Borno State prod. first difference	…	…	…	…	…	…	0.00 (0.12)
Adj. R^2	0.35	0.34	0.35	0.34	0.34	0.34	0.34
Adj. R^2 diff. from Base	…	-0.01	0	-0.01	-0.01	-0.01	-0.01

Figure 4B-1: Borno State urban maize price levels and ECM model estimation results

Note: t-statistics are in parentheses. ***, **, and * denote 1%, 5%, and 10% statistical significance, respectively. Critical values for the ADF and PP statistics associated with stationarity tests of estimated residuals ($\hat{v}_t$) for n=100 are -2.60, -1.95, and -1.61, for 1%, 5%, and 10% levels, respectively. All critical values are provided in Fuller (1996). A statistically significant estimated ECM term ($\hat{\gamma}$) implies cointegration (Banerjee et al. 1986). LS is an abbreviation for “lean season”.

Levels models

	Base	with Northern Nigeria interactions	with Borno State interactions	with both interactions
Intercept	8.35*** (3.26)	8.46*** (3.29)	8.46*** (3.30)	8.46*** (3.28)
Moundou, Chad price	0.84*** (16.23)	0.83*** (15.81)	0.83*** (15.81)	0.83*** (15.70)
LS x Northern Nigeria downward NDVI anomaly	…	0.12 (1.35)	…	0.12 (1.35)
LS x Northern Nigeria upward NDVI anomaly	…	0.02 (0.26)	…	-0.03 (-0.25)
LS x Borno State downward NDVI anomaly	…	…	0.12 (1.36)	…
LS x Borno State upward NDVI anomaly	…	…	0.04 (0.51)	0.06 (0.50)
ADF	-4.13***	-4.03***	-3.24***	-3.24***
PP	-3.98***	-3.91***	-3.28***	-3.29***
Adj. R^2	0.78	0.78	0.78	0.78

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.36*** (-4.69)	-0.36*** (-4.79)	-0.36*** (-4.61)	-0.36*** (-4.50)	-0.35*** (-4.54)	-0.36*** (-4.60)	-0.36*** (-4.66)
Moundou, Chad price first difference	0.19* (1.75)	0.18* (1.74)	0.20* (1.81)	0.17 (1.46)	0.17 (1.46)	0.19* (1.74)	0.19* (1.73)
Northern Nigeria downward NDVI anomaly	…	12.67** (2.51)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	-1.61 (-0.45)	…	…	…	…	…
Borno State downward NDVI anomaly	…	…	-1.17 (-0.49)	…	…	…	…
Borno State upward NDVI anomaly	…	…	-0.79 (-0.34)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	3.20 (0.33)	…	…	…
Borno State NDVI first difference	…	…	…	…	5.15 (0.69)	…	…
Nigerian national prod. first difference	…	...	…	…	…	-0.00 (-0.10)	…
Borno State prod. first difference	…	…	…	…	…	…	0.00 (0.14)
Adj. R^2	0.23	0.28	0.22	0.22	0.23	0.22	0.22
Adj. R^2 diff. from Base	…	+0.05	-0.01	-0.01	0	-0.01	-0.01

Figure 4B-2: Borno State urban millet price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Borno State interactions	with both interactions
Intercept	8.79*** (4.16)	9.58*** (4.76)	9.64*** (4.82)	9.95*** (4.95)
Niamey, Niger price	0.69*** (17.08)	0.66*** (16.84)	0.66*** (16.75)	0.65*** (16.43)
LS x Northern Nigeria downward NDVI anomaly	…	0.15*** (3.41)	…	0.05 (0.82)
LS x Northern Nigeria upward NDVI anomaly	…	0.09** (2.10)	…	0.09 (1.51)
LS x Borno State downward NDVI anomaly	…	…	0.13*** (3.74)	0.10* (1.85)
LS x Borno State upward NDVI anomaly	…	…	0.06* (1.66)	0.01 (0.12)
ADF	-3.25***	-4.81***	-5.19***	-5.10***
PP	-4.59***	-4.78***	-5.14***	-5.05***
Adj. R^2	0.73	0.76	0.76	0.76

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.39*** (-4.80)	-0.41*** (-5.01)	-0.39*** (-4.81)	-0.39*** (-4.84)	-0.40*** (-5.00)	-0.40*** (-4.85)	-0.38*** (-4.69)
Niamey, Niger price first difference	0.51*** (4.60)	0.49*** (4.42)	0.51*** (4.53)	0.47*** (4.11)	0.45*** (3.95)	0.50*** (4.44)	0.51*** (4.57)
Northern Nigeria downward NDVI anomaly	…	3.89* (1.73)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	-1.60 (-0.72)	…	…	…	…	…
Borno State downward NDVI anomaly	…	…	1.03 (0.65)	…	…	…	…
Borno State upward NDVI anomaly	…	…	-1.22 (-0.72)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	10.27 (1.62)	…	…	…
Borno State NDVI first difference	…	…	…	…	9.92* (1.91)	…	…
Nigerian national prod. first difference	…	...	…	…	…	-0.00 (-0.90)	…
Borno State prod. first difference	…	…	…	…	…	…	0.01 (0.75)
Adj. R^2	0.28	0.29	0.28	0.29	0.30	0.28	0.28
Adj. R^2 diff. from Base	…	+0.01	0	+0.01	+0.02	0	0

Figure 4B-3: Borno State urban sorghum price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Borno State interactions	with both interactions
Intercept	38.60*** (12.07)	37.05*** (11.51)	35.86*** (10.83)	34.27*** (10.39)
World Bank Thai 25% Broken Rice price	1.33*** (18.79)	1.35*** (19.03)	1.40*** (18.55)	1.43*** (19.11)
LS x Northern Nigeria downward NDVI anomaly	…	0.04 (0.34)	…	0.26* (1.86)
LS x Northern Nigeria upward NDVI anomaly	…	0.39** (2.33)	…	0.31* (1.76)
LS x Borno State downward NDVI anomaly	…	…	-0.13* (-1.69)	-0.25** (-2.50)
LS x Borno State upward NDVI anomaly	…	…	0.25* (1.84)	0.15 (1.07)
ADF	-2.02**	-1.88*	-2.06**	-1.99**
PP	-6.35***	-6.63***	-6.57***	-6.50***
Adj. R^2	0.78	0.78	0.78	0.79

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.48*** (-5.69)	-0.48*** (-5.58)	-0.48*** (-5.60)	-0.47*** (-5.52)	-0.48*** (-5.64)	-0.49*** (-5.60)	-0.49*** (-5.71)
World Bank Thai 25% Broken price first diff.	0.80** (2.51)	0.81** (2.52)	0.80** (2.51)	0.85*** (2.68)	0.79** (2.50)	0.70** (2.25)	0.85*** (2.60)
Northern Nigeria downward NDVI anomaly	…	-1.64 (-0.32)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	3.93 (0.78)	…	…	…	…	…
Borno State downward NDVI anomaly	…	…	3.10 (0.81)	…	…	…	…
Borno State upward NDVI anomaly	…	…	1.48 (0.39)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	19.71 (1.36)	…	…	…
Borno State NDVI first difference	…	…	…	…	11.58 (0.98)	…	…
Nigerian national prod. first difference	…	...	…	…	…	-0.02** (-2.56)	…
Borno State prod. first difference	…	…	…	…	…	…	-0.40 (-0.71)
Adj. R^2	0.28	0.27	0.27	0.28	0.28	0.32	0.27
Adj. R^2 diff. from Base	…	-0.01	-0.01	0	0	+0.04	-0.01

Figure 4B-4: Borno State urban local rice price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Borno State interactions	with both interactions
Intercept	48.04*** (14.79)	46.53*** (14.21)	46.02*** (13.48)	44.29*** (13.08)
World Bank Thai 25% Broken price	1.99*** (27.54)	2.00*** (27.71)	2.04*** (26.22)	2.07*** (27.00)
LS x Northern Nigeria downward NDVI anomaly	…	0.06 (0.49)	…	0.27* (1.86)
LS x Northern Nigeria upward NDVI anomaly	…	0.38** (2.25)	…	0.37** (2.01)
LS x Borno State downward NDVI anomaly	…	…	-0.12 (-1.50)	-0.24** (-2.35)
LS x Borno State upward NDVI anomaly	…	…	0.14 (1.01)	0.03 (0.19)
ADF	-4.50***	-4.67***	-4.58***	-6.56***
PP	-6.87***	-7.23***	-6.81***	-6.88***
Adj. R^2	0.88	0.89	0.88	0.89

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.54*** (-6.29)	-0.55*** (-6.37)	-0.54*** (-6.24)	-0.54*** (-6.07)	-0.55*** (-6.36)	-0.54*** (-6.45)	-0.52*** (-6.03)
World Bank Thai 25% Broken price first diff.	0.91*** (2.71)	0.93*** (2.77)	0.90*** (2.68)	0.90*** (2.66)	0.92*** (2.75)	0.83*** (2.50)	0.82** (2.36)
Northern Nigeria downward NDVI anomaly	…	-7.02 (-1.33)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	0.36 (0.07)	…	…	…	…	…
Borno State downward NDVI anomaly	…	…	-1.85 (-0.46)	…	…	…	…
Borno State upward NDVI anomaly	…	…	-0.05 (-0.01)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	-4.85 (-0.30)	…	…	…
Borno State NDVI first difference	…	…	…	…	-12.56 (-0.99)	…	…
Nigerian national prod. first difference	…	…	…	…	…	-0.02** (-2.00)	…
Borno State prod. first difference	…	…	…	…	…	…	0.59 (0.99)
Adj. R^2	0.29	0.29	0.28	0.28	0.29	0.31	0.29
Adj. R^2 diff. from Base	…	0	-0.01	-0.01	0	+0.02	0

Figure 4B-5: Borno State urban imported rice price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Borno State interactions	with both interactions
Intercept	58.21*** (23.38)	58.69*** (22.71)	59.54*** (23.29)	58.51*** (22.54)
GIEWS Bangkok, Thailand price	0.70*** (10.75)	0.65*** (9.25)	0.63*** (8.91)	0.65*** (9.14)
LS x Northern Nigeria downward NDVI anomaly	…	0.18** (2.13)	…	-0.02 (-0.10)
LS x Northern Nigeria upward NDVI anomaly	…	0.46*** (2.65)	…	0.44** (2.32)
LS x Borno State downward NDVI anomaly	…	…	0.19** (2.44)	0.20 (1.16)
LS x Borno State upward NDVI anomaly	…	…	0.17 (1.43)	0.06 (0.51)
ADF	-4.09***	-5.03***	-4.94***	-5.12***
PP	-4.96***	-5.04***	-4.91***	-5.11***
Adj. R^2	0.52	0.56	0.54	0.56

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.38*** (-4.64)	-0.36*** (-4.40)	-0.37*** (-4.50)	-0.35*** (-4.25)	-0.36*** (-4.46)	-0.37*** (-4.53)	-0.38*** (-4.61)
GIEWS Bangkok, Thailand price first diff.	0.95*** (2.71)	0.83*** (2.71)	0.94*** (2.61)	1.04*** (2.95)	1.01*** (2.91)	0.96*** (2.71)	0.96*** (2.70)
Northern Nigeria downward NDVI anomaly	…	8.94** (2.00)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	6.70 (1.51)	…	…	…	…	…
Borno State downward NDVI anomaly	…	…	1.08 (0.34)	…	…	…	…
Borno State upward NDVI anomaly	…	…	1.74 (0.51)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	21.06 (1.65)	…	…	…
Borno State NDVI first difference	…	…	…	…	22.65** (2.27)	…	…
Nigerian national prod. first difference	…	...	…	…	…	0.00 (0.86)	…
Borno State prod. first difference	…	…	…	…	…	…	0.41 (0.23)
Adj. R^2	0.21	0.24	0.20	0.22	0.24	0.21	0.20
Adj. R^2 diff. from Base	…	+0.03	-0.01	+0.01	+0.03	0	-0.01

Figure 4B-6: Borno State urban cassava price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Borno State interactions	with both interactions
Intercept	51.05*** (6.94)	57.11*** (7.48)	53.14*** (7.25)	54.78*** (7.40)
Accra, Ghana price	0.53*** (3.75)	0.38** (2.50)	0.49*** (3.27)	0.46*** (3.04)
LS x Northern Nigeria downward NDVI anomaly	…	0.32** (2.21)	…	0.28 (1.27)
LS x Northern Nigeria upward NDVI anomaly	…	…	…	…
LS x Borno State downward NDVI anomaly	…	…	0.18 (1.46)	-0.01 (-0.03)
LS x Borno State upward NDVI anomaly	…	…	-0.47** (-2.63)	-0.47** (-2.62)
ADF	-3.45***	-3.43***	-3.68***	-3.75***
PP	-3.41***	-3.41***	-3.70***	-3.79***
Adj. R^2	0.18	0.23	0.29	0.29

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.39*** (-3.66)	-0.38*** (-3.67)	-0.38*** (-3.53)	-0.39*** (-3.54)	-0.38*** (-3.53)	-0.40*** (-3.74)	…
Accra, Ghana price first diff.	0.13 (0.80)	0.12 (0.76)	0.11 (0.59)	0.13 (0.77)	0.14 (0.79)	0.15 (0.87)	…
Northern Nigeria downward NDVI anomaly	…	24.62* (1.86)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	…	…	…	…	…	…
Borno State downward NDVI anomaly	…	…	0.47 (0.07)	…	…	…	…
Borno State upward NDVI anomaly	…	…	-5.04 (-0.62)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	-4.54 (-0.17)	…	…	…
Borno State NDVI first difference	…	…	…	…	5.29 (0.26)	…	…
Nigerian national prod. first difference	…	...	…	…	…	0.00 (1.07)	…
Borno State prod. first difference	…	…	…	…	…	…	…
Adj. R^2	0.17	0.20	0.15	0.16	0.16	0.17	…
Adj. R^2 diff. from Base	…	+0.03	-0.02	-0.01	-0.01	0	…

Figure 4B-7: Borno State urban yams price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Borno State interactions	with both interactions
Intercept	31.67*** (3.85)	31.28*** (3.69)	34.32*** (3.66)	34.17*** (3.59)
Cotonou, Benin price	0.63*** (10.65)	0.63*** (10.18)	0.62*** (9.06)	0.62*** (8.94)
LS x Northern Nigeria downward NDVI anomaly	…	-0.01 (-0.24)	…	-0.01 (-0.16)
LS x Northern Nigeria upward NDVI anomaly	…	…	…	…
LS x Borno State downward NDVI anomaly	…	…	-0.01 (-0.13)	0.00 (0.03)
LS x Borno State upward NDVI anomaly	…	…	-0.12 (-0.73)	-0.12 (-0.71)
ADF	-4.20***	-4.25***	-4.22***	-4.25***
PP	-4.16***	-4.21***	-4.16***	-4.19***
Adj. R^2	0.71	0.70	0.70	0.69

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.34*** (-3.12)	-0.35*** (-3.13)	-0.36*** (-3.07)	-0.34*** (-2.89)	-0.33*** (-2.89)	-0.36*** (-3.11)	-0.38*** (-3.49)
Cotonou, Benin price first diff.	0.15 (1.43)	0.14 (1.30)	0.16 (1.45)	0.14 (1.25)	0.13 (1.18)	0.15 (1.38)	0.18* (1.76)
Northern Nigeria downward NDVI anomaly	…	14.80 (1.17)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	…	…	…	…	…	…
Borno State downward NDVI anomaly	…	…	-0.58 (-0.10)	…	…	…	…
Borno State upward NDVI anomaly	…	…	-2.88 (-0.37)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	15.02 (0.52)	…	…	…
Borno State NDVI first difference	…	…	…	…	22.50 (1.07)	…	…
Nigerian national prod. first difference	…	...	…	…	…	0.01 (0.46)	…
Borno State prod. first difference	…	…	…	…	…	…	0.95** (2.43)
Adj. R^2	0.14	0.15	0.11	0.13	0.15	0.13	0.23
Adj. R^2 diff. from Base	…	+0.01	-0.03	-0.01	+0.01	-0.01	+0.09

Figure 4B-8: Borno State urban cowpeas price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Kano State interactions	with both interactions
Intercept	10.58*** (7.10)	10.93*** (7.38)	10.49*** (7.00)	10.05*** (6.63)
Maradi, Niger price	0.71*** (20.76)	0.69*** (19.75	0.70*** (19.66)	0.70*** (19.44)
LS x Northern Nigeria downward NDVI anomaly	…	0.08* (1.93)	…	0.09** (2.15)
LS x Northern Nigeria upward NDVI anomaly	…	0.06 (1.30)	…	-0.09 (-1.29)
LS x Kano State downward NDVI anomaly	…	…	0.01 (0.35)	0.00 (0.03)
LS x Kano State upward NDVI anomaly	…	…	0.09** (2.50)	0.15*** (2.75)
ADF	-6.77***	-4.40***	-7.27***	-7.72***
PP	-6.81***	-7.18***	-7.31***	-7.79***
Adj. R^2	0.80	0.81	0.81	0.82

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals levels model	-0.70*** (-7.11)	-0.69*** (-7.33)	-0.68*** (-6.57)	-0.69*** (-7.57)	-0.68*** (-7.40)	-0.67*** (-7.12)	-0.67*** (-7.18)
Maradi, Niger price first difference	0.61*** (5.05)	0.58*** (4.82)	0.64*** (5.20)	0.57*** (4.95)	0.57*** (4.85)	0.61*** (5.07)	0.61*** (5.12)
N. Nigeria downward NDVI anomaly	…	4.42** (2.02)	…	…	…	…	…
N. Nigeria upward NDVI anomaly	…	1.28 (0.52)	…	…	…	…	…
Kano State downward NDVI anomaly	…	…	0.38 (0.17)	…	…	…	…
Kano State upward NDVI anomaly	…	…	2.17 (1.40)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	19.20*** (2.87)	…	…	…
Kano State NDVI first difference	…	…	…	…	14.95** (2.52)	…	…
Nigerian national prod. first difference	…	...	…	…	…	-0.00 (-0.31)	…
Kano State prod. first difference	…	…	…	…	…	…	-0.02 (-1.36)
Adj. R^2	0.40	0.41	0.40	0.43	0.43	0.39	0.40
Adj. R^2 difference from Base	…	+0.01	0	+0.03	+0.03	-0.01	0

Figure 4B-9: Kano State urban maize price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Kano State interactions	with both interactions
Intercept	9.89*** (3.57)	10.20*** (3.58)	6.70** (2.12)	7.01** (2.14)
Ouagadougou, Burkina Faso price	0.86*** (13.05)	0.85*** (12.36)	0.93*** (12.40)	0.92*** (11.56)
LS x Northern Nigeria downward NDVI anomaly	…	0.03 (0.56)	…	0.02 (0.40)
LS x Northern Nigeria upward NDVI anomaly	…	…	…	…
LS x Kano State downward NDVI anomaly	…	…	-0.06 (-1.04)	-0.05 (-0.93)
LS x Kano State upward NDVI anomaly	…	…	0.12* (1.82)	0.12* (1.81)
ADF	-3.60***	-3.57***	-3.37***	-3.32***
PP	-4.48***	-4.50***	-4.79***	-4.79***
Adj. R^2	0.78	0.78	0.79	0.79

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.53*** (-3.91)	-0.54*** (-3.82)	-0.52*** (-3.79)	-0.51*** (-3.77)	-0.52*** (-3.96)	-0.54*** (-4.07)	-0.53*** (-3.97)
Ouagadougou, Burkina Faso price first difference	0.33* (1.79)	0.33* (1.75)	0.34* (1.81)	0.27 (1.40)	0.21 (1.11)	0.32* (1.76)	0.30 (1.65)
Northern Nigeria downward NDVI anomaly	…	0.82 (0.19)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	…	…	…	…	…	…
Kano State downward NDVI anomaly	…	…	-1.01 (-0.35)	…	…	…	…
Kano State upward NDVI anomaly	…	…	2.02 (0.87)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	9.35 (1.03)	…	…	…
Kano State NDVI first difference	…	…	…	…	12.46 (1.60)	…	…
Nigerian national production first difference	…	…	…	…	…	-0.00 (-1.49)	…
Kano State production first difference	…	…	…	…	…	…	0.04 (1.03)
Adj. R^2	0.23	0.22	0.22	0.24	0.26	0.26	0.24
Adj. R^2 difference from Base	…	-0.01	-0.01	+0.01	+0.03	+0.03	+0.02

Figure 4B-10: Kano State urban millet price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Kano State interactions	with both interactions
Intercept	4.40** (2.12)	4.87** (2.43)	4.51** (2.12)	4.88** (2.32)
Niamey, Niger price	0.73*** (17.31)	0.70*** (16.92)	0.72*** (16.16)	0.70*** (15.96)
LS x Northern Nigeria downward NDVI anomaly	…	0.14*** (3.00)	…	0.14*** (2.92)
LS x Northern Nigeria upward NDVI anomaly	…	0.10** (2.17)	…	0.11 (1.49)
LS x Kano State downward NDVI anomaly	…	…	0.02 (0.35)	-0.00 (-0.04)
LS x Kano State upward NDVI anomaly	…	…	0.05 (1.20)	-0.00 (-0.09)
ADF	-2.82***	-3.35***	-2.87***	-3.35***
PP	-4.91***	-6.07***	-5.15***	-6.06***
Adj. R^2	0.74	0.76	0.73	0.76

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.43*** (-5.34)	-0.46*** (-5.76)	-0.43*** (-5.31)	-0.43*** (-5.48)	-0.43*** (-5.45)	-0.43*** (-5.30)	-0.43*** (-5.36)
Niamey, Niger price first difference	0.70*** (4.95)	0.67*** (4.78)	0.70*** (4.85)	0.61*** (4.13)	0.61*** (4.16)	0.70*** (4.89)	0.70*** (4.93)
Northern Nigeria downward NDVI anomaly	…	3.55 (1.39)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	4.72** (2.05)	…	…	…	…	…
Kano State downward NDVI anom.	…	…	2.38 (1.02)	…	…	…	…
Kano State upward NDVI anomaly	…	…	0.39 (0.25)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	16.20** (2.18)	…	…	…
Kano State NDVI first difference	…	…	…	…	12.54* (1.91)	…	…
Nigerian national prod. first difference	…	…	…	…	…	-0.00 (-0.27)	…
Kano State prod. first difference	…	…	…	…	…	…	-0.01 (-0.80)
Adj. R^2	0.31	0.34	0.31	0.34	0.33	0.31	0.31
Adj. R^2 difference from base	…	+0.03	0	+0.03	+0.02	0	0

Figure 4B-11: Kano State urban sorghum price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Kano State interactions	with both interactions
Intercept	29.51*** (13.72)	27.94*** (14.08)	27.63*** (13.46)	27.44*** (13.82)
World Bank Thai 25% broken rice price	1.30*** (24.89)	1.31*** (27.27)	1.30*** (26.31)	1.30*** (26.93)
LS x Northern Nigeria downward NDVI anomaly	…	0.07 (0.95)	…	0.08 (1.10)
LS x Northern Nigeria upward NDVI anomaly	…	0.56*** (4.86)	…	0.39*** (2.82)
LS x Kano State downward NDVI anomaly	…	…	0.10 (1.30)	0.10 (1.32)
LS x Kano State upward NDVI anomaly	…	…	0.33*** (4.42)	0.19** (2.15)
ADF	-1.69*	-2.70***	-2.63***	-2.68***
PP	-4.13***	-4.74***	-4.73***	-5.03***
Adj. R^2	0.85	0.88	0.87	0.88

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.28*** (-3.88)	-0.28*** (-3.92)	-0.28*** (-3.87)	-0.35*** (-5.02)	-0.33*** (-4.83)	-0.28*** (-3.69)	-0.28*** (-3.69)
World Bank Thai 25% broken rice price first difference	-0.02 (-0.06)	-0.02 (-0.08)	-0.06 (-0.19)	0.24 (0.79)	0.17 (0.58)	-0.02 (-0.06)	-0.03 (-0.10)
Northern Nigeria downward NDVI anomaly	…	1.14 (0.42)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	1.97 (0.65)	…	…	…	…	…
Kano State downward NDVI anomaly	…	…	1.53 (0.56)	…	…	…	…
Kano State upward NDVI anomaly	…	…	0.83 (0.45)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	31.02*** (3.65)	…	…	…
Kano State NDVI first difference	…	…	…	…	26.15*** (3.61)	…	…
Nigerian national prod. first difference	…	…	…	…	…	0.01 (0.92)	…
Kano State production first difference	…	…	…	…	…	…	0.14 (1.50)
Adj. R^2	0.11	0.10	0.10	0.20	0.20	0.11	0.12
Adj. R^2 difference from Base	…	-0.01	-0.10	+0.09	+0.09	0	+0.01

Figure 4B-12: Kano State urban local rice price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Kano State interactions	with both interactions
Intercept	9.51** (2.53)	8.57** (2.30)	6.56* (1.72)	6.63* (1.73)
Niamey, Niger price	1.28*** (29.41)	1.28*** (29.89)	1.31*** (29.41)	1.31*** (29.36)
LS x Northern Nigeria downward NDVI anomaly	…	-0.01 (-0.21)	…	-0.00 (-0.03)
LS x Northern Nigeria upward NDVI anomaly	…	0.16** (2.28)	…	0.12 (1.38)
LS x Kano State downward NDVI anomaly	…	…	-0.10* (-1.91)	-0.10* (-1.90)
LS x Kano State upward NDVI anomaly	…	…	0.09* (1.86)	0.04 (0.61)
ADF	-1.81*	-1.47	-5.41***	-5.61***
PP	-4.74***	-5.31***	-5.39***	-5.59***
Adj. R^2	0.89	0.89	0.90	0.90

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.40*** (-5.44)	-0.41*** (-5.69)	-0.40*** (-5.35)	-0.42*** (-5.66)	-0.42*** (-5.60)	-0.40*** (-5.42)	-0.40*** (-5.36)
Niamey, Niger price first difference	0.17 (0.69)	0.18 (0.76)	0.18 (0.74)	0.19 (0.78)	0.16 (0.66)	0.19 (0.77)	0.18 (0.73)
Northern Nigeria downward NDVI anomaly	…	0.97 (0.23)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	12.17** (2.61)	…	…	…	…	…
Kano State downward NDVI anomaly	…	…	0.28 (0.06)	…	…	…	…
Kano State upward NDVI anomaly	…	…	-0.04 (-0.01)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	19.46 (1.45)	…	…	…
Kano State NDVI first difference	…	…	…	…	14.68 (1.23)	…	…
Nigerian national prod. first difference	…	…	…	…	…	-0.00 (-0.19)	…
Kano State prod. first difference	…	…	…	…	…	…	-0.03 (-0.20)
Adj. R^2	0.21	0.24	0.19	0.22	0.21	0.20	0.20
Adj. R^2 difference from Base	…	+0.03	-0.02	+0.01	0	-0.01	-0.01

Figure 4B-13: Kano State urban imported rice price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Kano State interactions	with both interactions
Intercept	12.72*** (4.65)	12.81*** (5.12)	11.29*** (4.26)	10.76*** (4.43)
Malanville, Benin price	1.10*** (19.96)	1.08*** (20.98)	1.17*** (21.10)	1.15*** (22.48)
LS x Northern Nigeria downward NDVI anomaly	…	0.27*** (4.25)	…	0.27*** (4.65)
LS x Northern Nigeria upward NDVI anomaly	…	-0.13* (-1.67)	…	-0.17* (-1.66)
LS x Kano State downward NDVI anomaly	…	…	-0.20*** (-3.43)	-0.21*** (-3.96)
LS x Kano State upward NDVI anomaly	…	…	-0.11* (-1.81)	0.01 (0.15)
ADF	-5.59***	-6.90***	-5.90***	-7.31***
PP	-5.50***	-6.89***	-5.89***	-7.37***
Adj. R^2	0.80	0.83	0.82	0.85

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.51*** (-5.56)	-0.53*** (-6.38)	-0.51*** (-5.59)	-0.51*** (-5.60)	-0.51*** (-5.54)	-0.50*** (-5.40)	-0.50*** (-5.38)
Malanville, Benin price first difference	0.41*** (2.95)	0.38*** (2.92)	0.40*** (2.83)	0.40*** (2.84)	0.40*** (2.87)	0.40*** (2.81)	0.41*** (2.94)
Northern Nigeria downward NDVI anomaly	…	13.29*** (4.38)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	2.31 (0.68)	…	…	…	…	…
Kano State downward NDVI anomaly	…	…	1.89 (0.72)	…	…	…	…
Kano State upward NDVI anomaly	…	…	-2.59 (-1.05)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	12.82 (1.16)	…	…	…
Kano State NDVI first difference	…	…	…	…	7.18 (0.75)	…	…
Nigerian national prod. first difference	…	…	…	…	…	0.00 (0.61)	…
Kano State prod. first difference	…	…	…	…	…	…	-0.02 (-0.21)
Adj. R^2	0.24	0.36	0.24	0.24	0.24	0.24	0.23
Adj. R^2 difference from Base	…	+0.12	0	0	0	0	-0.01

Figure 4B-14: Kano State urban cassava price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Kano State interactions	with both interactions
Intercept	57.06*** (6.37)	59.98*** (6.15)	58.22*** (6.55)	61.03*** (6.31)
Accra, Ghana price	0.57*** (3.37)	0.50*** (2.58)	0.56*** (3.34)	0.49** (2.51)
LS x Northern Nigeria downward NDVI anomaly	…	0.13 (0.78)	…	0.13 (0.76)
LS x Northern Nigeria upward NDVI anomaly	…	…	…	…
LS x Kano State downward NDVI anomaly	…	…	0.20 (0.94)	0.22 (1.03)
LS x Kano State upward NDVI anomaly	…	…	-0.25 (-1.38)	-0.23 (-1.26)
ADF	0.80	0.80	-1.99**	-2.35**
PP	-4.70***	-4.69***	-4.90***	-4.90***
Adj. R^2	0.18	0.17	0.20	0.19

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.68*** (-5.20)	-0.68*** (-5.10)	-0.68*** (-5.17)	-0.70*** (-5.14)	-0.71*** (-5.14)	-0.66*** (-5.37)	…
Accra, Ghana price first difference	-0.35 (-1.38)	-0.35 (-1.37)	-0.42 (-1.65)	-0.36 (-1.40)	-0.38 (-1.46)	-0.32 (-1.37)	…
Northern Nigeria downward NDVI anomaly	…	2.26 (0.13)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	…	…	…	…	…	…
Kano State downward NDVI anomaly	…	…	0.76 (0.06)	…	…	…	…
Kano State upward NDVI anomaly	…	…	-17.36* (-1.71)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	-17.98 (-0.46)	…	…	…
Kano State NDVI first difference	…	…	…	…	-21.39 (-0.61)	…	…
Nigerian national prod. first difference	…	…	…	…	…	0.00*** (2.73)	…
Kano State prod. first difference	…	…	…	…	…	…	…
Adj. R^2	0.36	0.35	0.38	0.35	0.35	0.44	…
Adj. R^2 difference from Base	…	-0.01	+0.02	-0.01	-0.01	+0.08	…

Figure 4B-15: Kano State urban yams price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Kano State interactions	with both interactions
Intercept	19.17*** (2.92)	19.97*** (2.97)	19.21*** (2.84)	20.85*** (2.98)
Niamey, Niger price	1.10*** (12.83)	1.09*** (12.03)	1.13*** (12.40)	1.10*** (11.45)
LS x Northern Nigeria downward NDVI anomaly	…	0.08 (0.75)	…	0.07 (0.66)
LS x Northern Nigeria upward NDVI anomaly	…	-0.07 (-0.53)	…	0.14 (0.76)
LS x Kano State downward NDVI anomaly	…	…	-0.08 (-0.83)	-0.07 (-0.78)
LS x Kano State upward NDVI anomaly	…	…	-0.15 (-1.63)	-0.22 (-1.61)
ADF	-3.52***	-3.49***	-3.50***	-3.48***
PP	-3.69***	-3.67***	-3.73***	-3.76***
Adj. R^2	0.61	0.61	0.62	0.61

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.29*** (-4.59)	-0.28*** (-4.42)	-0.30*** (-4.59)	-0.31*** (-4.28)	-0.32*** (-4.58)	-0.33*** (-5.06)	-0.30*** (-4.58)
Niamey, Niger price first difference	0.05 (0.33)	-0.00 (-0.03)	0.03 (0.19)	0.06 (0.42)	0.07 (0.51)	0.04 (0.29)	0.04 (0.31)
Northern Nigeria downward NDVI anomaly	…	14.95** (2.09)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	-2.30 (-0.32)	…	…	…	…	…
Kano State downward NDVI anomaly	…	…	-0.36 (-0.07)	…	…	…	…
Kano State upward NDVI anomaly	…	…	-4.28 (-0.94)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	-12.15 (-0.51)	…	…	…
Kano State NDVI first difference	…	…	…	…	-18.72 (-0.94)	…	…
Nigerian national prod. first difference	…	…	…	…	…	-0.05** (-2.05)	…
Kano State prod. first difference	…	…	…	…	…	…	0.39 (0.31)
Adj. R^2	0.16	0.18	0.15	0.16	0.16	0.19	0.16
Adj. R^2 difference from Base	…	+0.02	-0.01	0	0	+0.03	0

Figure 4B-16: Kano State urban cowpeas price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Katsina State interactions	with both interactions
Intercept	7.03*** (4.12)	7.05*** (4.09)	7.13*** (4.06)	7.01*** (3.93)
Maradi, Niger price	0.79*** (21.19)	0.79*** (20.58)	0.78*** (19.69)	0.79*** (19.41)
LS x Northern Nigeria downward NDVI anomaly	…	0.01 (0.22)	…	-0.03 (-0.45)
LS x Northern Nigeria upward NDVI anomaly	…	0.01 (0.18)	…	-0.05 (-0.54)
LS x Katsina State downward NDVI anomaly	…	…	0.02 (0.29)	0.01 (0.26)
LS x Katsina State upward NDVI anomaly	…	…	0.03 (0.72)	0.06 (0.86)
ADF	-6.13***	-6.16***	-6.23***	-6.20***
PP	-6.08***	-6.11***	-6.18***	-6.16***
Adj. R^2	0.79	0.79	0.79	0.78

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.52*** (-7.14)	-0.51*** (-7.08)	-0.51*** (-7.07)	-0.49*** (-6.54)	-0.49*** (-6.69)	-0.52*** (-7.10)	-0.52*** (-7.16)
Maradi, Niger price first difference	0.21* (1.95)	0.20* (1.81)	0.23* (2.07)	0.20* (1.82)	0.19* (1.71)	0.21* (1.90)	0.23** (2.05)
Northern Nigeria downward NDVI anomaly	…	0.49 (0.21)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	1.68 (0.65)	…	…	…	…	…
Katsina State downward NDVI anomaly	…	…	-2.69 (-1.17)	…	…	…	…
Katsina State upward NDVI anomaly	…	…	-0.03 (-0.03)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	9.10 (1.31)	…	…	…
Katsina State NDVI first difference	…	…	…	…	8.94 (1.35)	…	…
Nigerian national prod. first difference	…	...	…	…	…	0.00 (0.06)	…
Katsina State prod. first difference	…	…	…	…	…	…	-0.08 (-0.70)
Adj. R^2	0.32	0.31	0.31	0.32	0.32	0.31	0.31
Adj. R^2 diff. from Base	…	-0.01	-0.01	0	0	-0.01	-0.01

Figure 4B-17: Katsina State urban maize price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Katsina State interactions	with both interactions
Intercept	12.68*** (5.03)	12.71*** (4.90)	12.68*** (4.98)	12.63*** (4.66)
Ouagadougou, Burkina Faso price	0.83*** (13.85)	0.83*** (13.21)	0.83*** (13.59)	0.83*** (12.83)
LS x Northern Nigeria downward NDVI anomaly	…	0.00 (0.06)	…	-0.01 (-0.06)
LS x Northern Nigeria upward NDVI anomaly	…	…	…	…
LS x Katsina State downward NDVI anomaly	…	…	…	…
LS x Katsina State upward NDVI anomaly	…	…	0.01 (0.11)	0.01 (0.11)
ADF	-5.82***	-5.82***	-5.81***	-5.81***
PP	-5.81***	-5.80***	-5.80***	-5.80***
Adj. R^2	0.80	0.80	0.80	0.79

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.74*** (-4.96)	-0.76*** (-4.99)	-0.61*** (-3.69)	-0.75*** (-4.85)	-0.73*** (-4.80)	-0.74*** (-5.00)	-0.74*** (-4.90)
Ouagadougou, Burkina Faso price first diff.	0.37* (1.92)	0.35* (1.75)	0.31 (1.61)	0.38* (1.82)	0.32* (1.47)	0.35* (1.84)	0.37* (1.88)
Northern Nigeria downward NDVI anomaly	…	3.18 (0.74)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	…	…	…	…	…	…
Katsina State downward NDVI anomaly	…	…	-5.68* (-1.77)	…	…	…	…
Katsina State upward NDVI anomaly	…	…	-0.91 (-0.59)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	-0.91 (-0.10)	…	…	…
Katsina State NDVI first difference	…	…	…	…	5.66 (0.62)	…	…
Nigerian national prod. first difference	…	...	…	…	…	-0.00 (-1.39)	…
Katsina State prod. first difference	…	…	…	…	…	…	-0.02 (-0.04)
Adj. R^2	0.33	0.32	0.35	0.31	0.32	0.34	0.31
Adj. R^2 diff. from Base	…	-0.01	+0.02	-0.02	-0.01	+0.01	-0.02

Figure 4B-18: Katsina State urban millet price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Katsina State interactions	with both interactions
Intercept	-3.12 (-1.34)	-3.74* (-1.71)	-2.52 (-1.10)	-3.08 (-1.43)
Niamey, Niger price	0.89*** (19.02)	0.88*** (19.98)	0.86*** (18.34)	0.86*** (19.64)
LS x Northern Nigeria downward NDVI anomaly	…	0.23*** (4.51)	…	0.26*** (3.94)
LS x Northern Nigeria upward NDVI anomaly	…	-0.04 (-0.76)	…	0.00 (0.01)
LS x Katsina State downward NDVI anomaly	…	…	0.16** (2.24)	0.17** (2.47)
LS x Katsina State upward NDVI anomaly	…	…	0.05 (1.33)	-0.03 (-0.53)
ADF	-4.04***	-4.13***	-4.12***	-4.42***
PP	-4.58***	-4.83***	-4.79***	-5.14***
Adj. R^2	0.75	0.79	0.76	0.80

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.27*** (-3.62)	-0.28*** (-3.88)	-0.27*** (-3.58)	-0.25*** (-3.41)	-0.25*** (-3.42)	-0.27*** (-3.59)	-0.26*** (-3.58)
Niamey, Niger price first diff.	0.48*** (3.60)	0.46*** (3.47)	0.49*** (3.59)	0.39*** (2.88)	0.37*** (2.71)	0.48*** (3.55)	0.48*** (3.58)
Northern Nigeria downward NDVI anomaly	…	4.72* (1.96)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	0.93 (0.35)	…	…	…	…	…
Katsina State downward NDVI anomaly	…	…	0.34 (0.14)	…	…	…	…
Katsina State upward NDVI anomaly	…	…	0.51 (0.37)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	17.55** (2.44)	…	…	…
Katsina State NDVI first difference	…	…	…	…	18.46*** (2.67)	…	…
Nigerian national prod. first difference	…	...	…	…	…	-0.00 (-0.11)	…
Katsina State prod. first difference	…	…	…	…	…	…	0.01 (0.13)
Adj. R^2	0.15	0.16	0.13	0.18	0.19	0.14	0.14
Adj. R^2 diff. from Base	…	+0.01	-0.02	+0.03	+0.04	-0.01	-0.01

Figure 4B-19: Katsina State urban sorghum price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Katsina State interactions	with both interactions
Intercept	11.01*** (4.28)	10.03*** (3.96)	10.21*** (4.25)	10.01*** (4.25)
Niamey, Niger price	0.75*** (26.12)	0.76*** (26.82)	0.74*** (27.47)	0.74*** (27.79)
LS x Northern Nigeria downward NDVI anomaly	…	0.04 (0.92)	…	-0.10** (-2.05)
LS x Northern Nigeria upward NDVI anomaly	…	0.13*** (3.96)	…	-0.03 (-0.56)
LS x Katsina State downward NDVI anomaly	…	…	0.09** (2.09)	0.09** (2.08)
LS x Katsina State upward NDVI anomaly	…	…	0.12*** (4.60)	0.18*** (4.06)
ADF	-5.48***	-5.60***	-4.23***	-4.34***
PP	-5.59***	-5.70***	-6.46***	-6.78***
Adj. R^2	0.85	0.86	0.88	0.88

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.50*** (-5.93)	-0.50*** (-5.97)	-0.52*** (-6.09)	-0.53*** (-6.39)	-0.52*** (-6.37)	-0.49*** (-5.87)	-0.50*** (-5.87)
Niamey, Niger price first diff.	0.26* (1.85)	0.24* (1.71)	0.22 (1.53)	0.25* (1.85)	0.21 (1.53)	0.25* (1.84)	0.26* (1.88)
Northern Nigeria downward NDVI anomaly	…	3.62 (1.10)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	2.42 (0.66)	…	…	…	…	…
Katsina State downward NDVI anomaly	…	…	4.79 (1.40)	…	…	…	…
Katsina State upward NDVI anomaly	…	…	0.04 (0.02)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	26.76*** (2.83)	…	…	…
Katsina State NDVI first difference	…	…	…	…	26.39*** (2.92)	…	…
Nigerian national prod. first difference	…	...	…	…	…	-0.01** (-2.24)	…
Katsina State prod. first difference	…	…	…	…	…	…	0.14 (0.40)
Adj. R^2	0.23	0.23	0.23	0.27	0.28	0.25	0.22
Adj. R^2 diff. from Base	…	0	0	+0.04	+0.05	+0.02	-0.01

Figure 4B-20: Katsina State urban local rice price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Katsina State interactions	with both interactions
Intercept	7.29** (2.16)	6.89** (2.01)	6.71** (1.97)	6.71** (1.97)
Niamey, Niger price	1.15*** (30.50)	1.16*** (30.35)	1.15*** (29.99)	1.15*** (30.08)
LS x Northern Nigeria downward NDVI anomaly	…	-0.00 (-0.00)	…	-0.12* (-1.68)
LS x Northern Nigeria upward NDVI anomaly	…	0.06 (0.92)	…	-0.08 (-0.93)
LS x Katsina State downward NDVI anomaly	…	…	0.04 (0.73)	0.04 (0.71)
LS x Katsina State upward NDVI anomaly	…	…	0.08** (2.00)	0.15** (2.43)
ADF	-6.24***	-6.31***	-6.46***	-6.57***
PP	-6.30***	-6.36***	-6.48***	-6.59***
Adj. R^2	0.89	0.89	0.89	0.90

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.51*** (-6.34)	-0.51*** (-6.29)	-0.53*** (-6.53)	-0.52*** (-6.54)	-0.52*** (-6.47)	-0.50*** (-6.25)	-0.51*** (-6.31)
Niamey, Niger price first diff.	0.31 (1.64)	0.30 (1.56)	0.24 (1.27)	0.31 (1.63)	0.28 (1.47)	0.31 (1.62)	0.31 (1.63)
Northern Nigeria downward NDVI anomaly	…	2.53 (0.56)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	3.97 (0.79)	…	…	…	…	…
Katsina State downward NDVI anomaly	…	…	8.19* (1.79)	…	…	…	…
Katsina State upward NDVI anomaly	…	…	-0.28 (-0.11)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	21.75* (1.66)	…	…	…
Katsina State NDVI first difference	…	…	…	…	17.79 (1.41)	…	…
Nigerian national prod. first difference	…	...	…	…	…	-0.01 (-0.68)	…
Katsina State prod. first difference	…	…	…	…	…	…	0.03 (0.05)
Adj. R^2	0.25	0.24	0.26	0.26	0.25	0.24	0.24
Adj. R^2 diff. from Base	…	-0.01	+0.01	+0.01	0	-0.01	-0.01

Figure 4B-21: Katsina State urban imported rice price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Katsina State interactions	with both interactions
Intercept	23.90*** (9.00)	23.64*** (9.63)	23.69*** (8.90)	23.48*** (9.55)
Malanville, Benin price	0.96*** (17.82)	0.96*** (18.95)	0.97*** (17.53)	0.97*** (18.94)
LS x Northern Nigeria downward NDVI anomaly	…	0.16*** (2.62)	…	0.17* (1.92)
LS x Northern Nigeria upward NDVI anomaly	…	-0.25*** (-3.31)	…	-0.24** (-2.17)
LS x Katsina State downward NDVI anomaly	…	…	-0.13 (-1.30)	-0.13 (-1.37)
LS x Katsina State upward NDVI anomaly	…	…	-0.03 (-0.55)	-0.02 (-0.26)
ADF	-2.95***	-1.70*	-2.89***	-1.55
PP	-3.34***	-4.32***	-3.33***	-4.30***
Adj. R^2	0.76	0.79	0.76	0.79

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.13** (-2.17)	-0.12** (-2.10)	-0.10* (-1.80)	-0.13** (-2.17)	-0.13** (-2.20)	-0.12** (-2.07)	-0.13** (-2.25)
Malanville, Benin price first diff.	0.18** (1.98)	0.15* (1.67)	0.15* (1.71)	0.18** (1.99)	0.19** (2.02)	0.17* (1.86)	0.18* (1.94)
Northern Nigeria downward NDVI anomaly	…	1.81 (0.85)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	4.69* (1.98)	…	…	…	…	…
Katsina State downward NDVI anomaly	…	…	-4.43** (-2.10)	…	…	…	…
Katsina State upward NDVI anomaly	…	…	1.49 (1.19)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	-2.04 (-0.28)	…	…	…
Katsina State NDVI first difference	…	…	…	…	-3.14 (-0.46)	…	…
Nigerian national prod. first difference	…	...	…	…	…	0.00 (0.55)	…
Katsina State prod. first difference	…	…	…	…	…	…	-0.03 (-0.80)
Adj. R^2	0.04	0.07	0.08	0.03	0.04	0.04	0.04
Adj. R^2 diff. from Base	…	+0.03	+0.04	-0.01	0	0	0

Figure 4B-22: Katsina State urban cassava price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Katsina State interactions	with both interactions
Intercept	92.47*** (12.00)	92.60*** (11.75)	91.98*** (11.75)	94.14*** (11.89)
Bolgatanga, Ghana price	0.39** (2.60)	0.38** (2.47)	0.41** (2.63)	0.37** (2.37)
LS x Northern Nigeria downward NDVI anomaly	…	0.02 (0.10)	…	0.83 (1.50)
LS x Northern Nigeria upward NDVI anomaly	…	…	…	…
LS x Katsina State downward NDVI anomaly	…	…	-0.10 (-0.51)	-0.10 (-0.51)
LS x Katsina State upward NDVI anomaly	…	…	-0.07 (-0.43)	-0.82 (-1.56)
ADF	-4.85***	-4.86***	-4.83***	-5.39***
PP	-4.80***	-4.81***	-4.79***	-5.37***
Adj. R^2	0.09	0.08	0.07	0.09

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.57*** (-4.82)	-0.57*** (-4.71)	-0.58*** (-4.80)	-0.58*** (-4.87)	-0.57*** (-4.84)	-0.56*** (-4.70)	-0.57*** (-4.77)
Bolgatanga, Ghana price first diff.	0.20 (0.96)	0.20 (0.97)	0.16 (0.75)	0.20 (0.95)	0.21 (1.00)	0.20 (0.95)	0.20 (0.94)
Northern Nigeria downward NDVI anomaly	…	-4.36 (-0.27)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	…	…	…	…	…	…
Katsina State downward NDVI anomaly	…	…	-3.40 (-0.43)	…	…	…	…
Katsina State upward NDVI anomaly	…	…	-4.46 (-0.67)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	-29.09 (-0.95)	…	…	…
Katsina State NDVI first difference	…	…	…	…	-22.10 (-0.77)	…	…
Nigerian national prod. first difference	…	...	…	…	…	-0.00 (-0.47)	…
Katsina State prod. first difference	…	…	…	…	…	…	0.14 (0.17)
Adj. R^2	0.29	0.28	0.27	0.29	0.28	0.28	0.28
Adj. R^2 diff. from Base	…	-0.01	-0.02	0	-0.01	-0.01	-0.01

Figure 4B-23: Katsina State urban yams price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Levels models

	Base	with Northern Nigeria interactions	with Katsina State interactions	with both interactions
Intercept	10.48* (1.67)	8.87 (1.41)	9.85 (1.56)	10.06 (1.56)
Niamey, Niger price	1.07*** (13.01)	1.12*** (13.17)	1.10*** (12.69)	1.11*** (12.39)
LS x Northern Nigeria downward NDVI anomaly	…	-0.12 (-1.17)	…	-0.00 (-0.02)
LS x Northern Nigeria upward NDVI anomaly	…	-0.24** (-2.10)	…	-0.11 (-0.60)
LS x Katsina State downward NDVI anomaly	…	…	0.10 (0.82)	0.10 (0.82)
LS x Katsina State upward NDVI anomaly	…	…	-0.18** (-2.29)	-0.13 (-0.95)
ADF	-1.53	-1.74*	-1.84*	-1.87*
PP	-3.71***	-3.72***	-3.75***	-3.78***
Adj. R^2	0.62	0.63	0.64	0.63

ECM models

	base	with N Nigerian NDVI anomalies	with state NDVI anomalies	with N Nigerian NDVI diffs.	with state NDVI diffs.	with national prod. diffs.	with state prod. diffs.
Lagged residuals base levels model	-0.22*** (-3.82)	-0.22*** (-3.73)	-0.22*** (-3.68)	-0.22*** (-3.57)	-0.21*** (-3.51)	-0.26*** (-4.49)	-0.24*** (-3.95)
Niamey, Niger price first diff.	0.08 (0.64)	0.07 (0.61)	0.09 (0.71)	0.08 (0.61)	0.06 (0.50)	0.08 (0.71)	0.07 (0.57)
Northern Nigeria downward NDVI anomaly	…	0.81 (0.13)	…	…	…	…	…
Northern Nigeria upward NDVI anomaly	…	0.26 (0.04)	…	…	…	…	…
Katsina State downward NDVI anomaly	…	…	3.57 (0.63)	…	…	…	…
Katsina State upward NDVI anomaly	…	…	1.53 (0.43)	…	…	…	…
Northern Nigeria NDVI first difference	…	…	…	0.49 (0.02)	…	…	…
Katsina State NDVI first difference	…	…	…	…	7.68 (0.41)	…	…
Nigerian national prod. first difference	…	…	…	…	…	-0.05** (-2.53)	…
Katsina State prod. first difference	…	…	…	…	…	…	0.10 (0.98)
Adj. R^2	0.11	0.10	0.10	0.10	0.11	0.16	0.11
Adj. R^2 diff. from Base	…	-0.01	-0.01	-0.01	0	+0.05	0

Figure 4B-24: Katsina State urban cowpeas price levels and ECM model estimation results

Note: a description of table contents is included below figure 4B-1.

Appendix 4C. Comprehensive Results for the Rural Price Model Set

Levels models

	Base	with interactions
Intercept	25.63*** (4.94)	22.37*** (3.95)
Borno State urban price	0.51*** (5.38)	0.55*** (5.38)
LS x Borno State downward NDVI anomaly	…	0.03 (0.52)
LS x Borno State upward NDVI anomaly	…	0.28 (1.62)
ADF	-4.61***	-4.55***
PP	-4.51***	-4.45***
Adj. R^2	0.37	0.38

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.53*** (-3.62)	-0.63*** (-4.15)	-0.61*** (-4.21)	-0.61*** (-3.49)
Borno State urban price first difference	0.36** (2.50)	0.41*** (2.83)	0.35** (2.52)	0.36** (2.46)
Borno State downward NDVI anomaly	…	7.02* (1.79)	…	…
Borno State upward NDVI anomaly	…	4.47 (0.91)	…	…
Borno State NDVI first difference	…	…	30.50** (2.24)	…
Borno State production first difference	…	…	…	-0.02 (-0.09)
Adj. R^2	0.22	0.25	0.29	0.20
Adj. R^2 difference from Base	…	+0.03	+0.07	-0.02

Figure 4C-1: Borno State rural maize price levels and ECM model estimation results

Note: t-statistics are in parentheses. ***, **, and * denote 1%, 5%, and 10% statistical significance, respectively. Critical values for the ADF and PP statistics associated with stationarity tests of estimated residuals ($\hat{v}_t$) for n=50 are -2.62, -1.95, and -1.60, for 1%, 5%, and 10% levels, respectively. All critical values are provided in Fuller (1996). A statistically significant estimated ECM term ($\hat{\gamma}$) implies cointegration (Banerjee et al. 1986). LS is an abbreviation for "lean season".

Levels models

	Base	with interactions
Intercept	18.94*** (5.23)	15.23*** (3.88)
Borno State urban price	0.44*** (7.19)	0.49*** (7.53)
LS x Borno State downward NDVI anomaly	…	0.09 (1.47)
LS x Borno State upward NDVI anomaly	…	0.26* (1.98)
ADF	-3.43***	-3.70***
PP	-3.32***	-3.59***
Adj. R^2	0.59	0.63

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.32** (-2.12)	-0.35** (-2.20)	-0.29* (-1.96)	-0.31** (-1.92)
Borno State urban price first difference	0.06 (0.40)	0.10 (0.59)	0.01 (0.05)	0.05 (0.22)
Borno State downward NDVI anomaly	…	2.52 (1.09)	…	…
Borno State upward NDVI anomaly	…	1.02 (0.38)	…	…
Borno State NDVI first difference	…	…	14.50* (1.77)	…
Borno State production first difference	…	…	…	-0.03 (-0.09)
Adj. R^2	0.08	0.06	0.14	0.05
Adj. R^2 difference from Base	…	-0.02	+0.06	-0.03

Figure 4C-2: Borno State rural millet price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	5.82 (1.11)	-1.69 (-0.29)
Borno State urban price	0.86*** (8.32)	1.02*** (8.80)
LS x Borno State downward NDVI anomaly	…	-0.11** (-2.12)
LS x Borno State upward NDVI anomaly	…	0.20 (1.66)
ADF	-6.04***	-0.98
PP	-6.00***	-6.02***
Adj. R^2	0.59	0.63

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.83*** (-5.20)	-0.87*** (-5.69)	-0.83*** (-5.17)	-0.80*** (-4.74)
Borno State urban price first difference	0.31 (1.63)	0.25 (1.38)	0.30 (1.56)	0.25 (1.09)
Borno State downward NDVI anomaly	…	6.79** (2.56)	…	…
Borno State upward NDVI anomaly	…	5.14 (1.52)	…	…
Borno State NDVI first difference	…	…	5.38 (0.53)	…
Borno State production first difference	…	…	…	0.04 (0.70)
Adj. R^2	0.35	0.44	0.34	0.34
Adj. R^2 difference from Base	…	+0.09	-0.01	-0.01

Figure 4C-3: Borno State rural sorghum price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	19.18 (1.59)	25.03* (1.96)
Borno State urban price	0.78*** (7.57)	0.73*** (6.73)
LS x Borno State downward NDVI anomaly	…	0.00 (0.07)
LS x Borno State upward NDVI anomaly	…	-0.14 (-1.67)
ADF	-4.68***	-4.90***
PP	-4.60***	-4.78***
Adj. R^2	0.54	0.55

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.55*** (-4.10)	-0.53*** (-3.97)	-0.55*** (-4.09)	-0.53*** (-3.93)
Borno State urban price first difference	0.40*** (3.30)	0.40*** (3.35)	0.39*** (3.20)	0.37*** (3.06)
Borno State downward NDVI anomaly	…	6.38 (1.28)	…	…
Borno State upward NDVI anomaly	…	5.85 (0.91)	…	…
Borno State NDVI first difference	…	…	12.17 (0.67)	…
Borno State production first difference	...	…	…	0.79 (1.16)
Adj. R^2	0.30	0.31	0.29	0.30
Adj. R^2 difference from Base	…	+0.01	-0.01	0

Figure 4C-4: Borno State rural local rice price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	30.01** (2.13)	31.73* (1.95)
Borno State urban price	0.82*** (9.58)	0.80*** (8.12)
LS x Borno State downward NDVI anomaly	…	0.01 (0.28)
LS x Borno State upward NDVI anomaly	…	-0.01 (-0.09)
ADF	-5.68***	-5.67***
PP	-5.79***	-5.77***
Adj. R^2	0.66	0.64

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.54*** (-3.95)	-0.59*** (-4.38)	-0.58*** (-4.21)	-0.54*** (-3.92)
Borno State urban price first difference	0.18 (1.26)	0.20 (1.49)	0.20 (1.49)	0.19 (1.30)
Borno State downward NDVI anomaly	…	11.14** (2.03)	…	…
Borno State upward NDVI anomaly	…	-9.08 (-1.31)	…	…
Borno State NDVI first difference	…	…	29.33 (1.43)	…
Borno State production first difference	...	…	…	-0.27 (-0.35)
Adj. R^2	0.23	0.29	0.25	0.21
Adj. R^2 difference from Base	…	+0.06	+0.02	-0.02

Figure 4C-5: Borno State rural imported rice price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	38.04*** (4.37)	41.70*** (4.54)
Borno State urban price	0.53*** (5.66)	0.50*** (4.89)
LS x Borno State downward NDVI anomaly	…	0.01 (0.24)
LS x Borno State upward NDVI anomaly	…	-0.18** (-2.67)
ADF	-4.65***	-4.93***
PP	-4.67***	-4.88***
Adj. R^2	0.40	0.46

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.53*** (-3.51)	-0.51*** (-3.39)	-0.54*** (-3.52)	-0.55*** (-3.77)
Borno State urban price first difference	0.20 (1.62)	0.20 (1.63)	0.20 (1.66)	0.19 (1.64)
Borno State downward NDVI anomaly	…	4.66 (1.12)	…	…
Borno State upward NDVI anomaly	…	4.64 (0.85)	…	…
Borno State NDVI first difference	…	…	-8.09 (-0.52)	…
Borno State production first difference	...	…	…	3.49* (1.92)
Adj. R^2	0.20	0.19	0.18	0.24
Adj. R^2 difference from Base	…	-0.01	-0.02	+0.04

Figure 4C-6: Borno State rural cassava price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	32.86*** (2.89)	31.44*** (2.41)
Borno State urban price	0.54*** (3.82)	0.56*** (3.35)
LS x Borno State downward NDVI anomaly	…	0.00 (0.03)
LS x Borno State upward NDVI anomaly	…	0.09 (0.35)
ADF	-6.42***	-6.49***
PP	-4.78***	-4.82***
Adj. R^2	0.22	0.19

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.73*** (-4.94)	-0.81*** (-5.23)	-0.73*** (-4.88)	…
Borno State urban price first difference	0.27 (1.22)	0.34 (1.52)	0.27 (1.20)	…
Borno State downward NDVI anomaly	…	3.35 (0.38)	…	…
Borno State upward NDVI anomaly	…	18.79 (1.57)	…	…
Borno State NDVI first difference	…	…	0.44 (0.01)	…
Borno State production first difference	…	…	…	…
Adj. R^2	0.33	0.34	0.31	…
Adj. R^2 difference from Base	…	+0.01	-0.02	…

Figure 4C-7: Borno State rural yams price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	8.06 (1.28)	7.63 (1.09)
Borno State urban price	0.91*** (17.36)	0.93*** (15.84)
LS x Borno State downward NDVI anomaly	…	-0.05 (-1.27)
LS x Borno State upward NDVI anomaly	…	-0.03 (-0.26)
ADF	-6.46***	-6.76***
PP	-6.70***	-6.79***
Adj. R^2	0.86	0.86

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.89*** (-6.40)	-0.95*** (-6.87)	-0.88*** (-6.31)	-0.90*** (-6.92)
Borno State urban price first difference	0.55*** (4.68)	0.56*** (4.86)	0.58*** (4.75)	0.47*** (4.14)
Borno State downward NDVI anomaly	…	9.41* (1.97)	…	…
Borno State upward NDVI anomaly	…	5.51 (0.90)	…	…
Borno State NDVI first difference	…	…	-16.07 (-0.89)	…
Borno State production first difference	...	…	…	0.92*** (2.72)
Adj. R^2	0.52	0.54	0.51	0.58
Adj. R^2 difference from Base	…	+0.02	-0.01	+0.06

Figure 4C-8: Borno State rural cowpeas price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	-1.48 (-0.43)	-0.60 (-0.17)
Kano State urban price	1.05*** (15.01)	1.03*** (15.01)
LS x Kano State downward NDVI anomaly	…	0.04 (0.82)
LS x Kano State upward NDVI anomaly	…	-0.06 (-1.66)
ADF	-4.32***	-4.98***
PP	-4.24***	-4.90***
Adj. R^2	0.87	0.87

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.81*** (-5.41)	-0.80*** (-5.29)	-0.79*** (-5.04)	-0.80*** (-5.27)
Kano State urban price first difference	0.59*** (4.26)	0.59*** (4.11)	0.57*** (3.68)	0.59*** (4.18)
Kano State downward NDVI anomaly	…	-2.35 (-0.98)	…	…
Kano State upward NDVI anomaly	…	-1.74 (-0.72)	…	…
Kano State NDVI first difference	…	…	2.81 (0.35)	…
Kano State production first difference	...	…	…	-0.03 (-0.15)
Adj. R^2	0.55	0.54	0.54	0.53
Adj. R^2 difference from Base	…	-0.01	-0.01	-0.02

Figure 4C-9: Kano State rural maize price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	2.73 (0.71)	3.96 (0.99)
Kano State urban price	0.91*** (11.52)	0.87*** (10.42)
LS x Kano State downward NDVI anomaly	…	0.06 (1.29)
LS x Kano State upward NDVI anomaly	…	0.02 (0.49)
ADF	-5.04***	-5.25***
PP	-5.37***	-5.87***
Adj. R^2	0.79	0.79

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.43*** (-2.92)	-0.44*** (-2.94)	-0.40*** (-2.94)	-0.66*** (-3.66)
Kano State urban price first difference	0.38** (2.03)	0.39** (2.04)	0.30 (1.54)	0.58* (1.91)
Kano State downward NDVI anomaly	…	3.07 (1.42)	…	…
Kano State upward NDVI anomaly	…	-0.40 (-0.18)	…	…
Kano State NDVI first difference	…	…	9.76 (1.47)	…
Kano State production first difference	…	…	…	-0.03 (-0.28)
Adj. R^2	0.17	0.17	0.19	0.03
Adj. R^2 difference from Base	…	0	+0.02	-0.14

Figure 4C-10: Kano State rural millet price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	1.38 (0.40)	2.37 (0.68)
Kano State urban price	0.92*** (12.81)	0.90*** (12.04)
LS x Kano State downward NDVI anomaly	…	0.04 (0.92)
LS x Kano State upward NDVI anomaly	…	-0.04 (-1.08)
ADF	-4.14***	-4.50***
PP	-4.00***	-4.40***
Adj. R^2	0.82	0.83

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.42*** (-3.08)	-0.44*** (-3.25)	-0.39*** (-2.85)	-0.42*** (-3.03)
Kano State urban price first difference	0.29** (2.37)	0.28** (2.23)	0.25* (1.99)	0.29** (2.33)
Kano State downward NDVI anomaly	…	3.02 (1.48)	…	…
Kano State upward NDVI anomaly	…	-1.58 (-0.78)	…	…
Kano State NDVI first difference	…	…	8.15 (1.31)	…
Kano State production first difference	...	…	…	-0.01 (-0.11)
Adj. R^2	0.21	0.23	0.22	0.18
Adj. R^2 difference from Base	…	+0.02	+0.01	-0.03

Figure 4C-11: Kano State rural sorghum price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	32.05*** (4.95)	36.03*** (5.50)
Kano State urban price	0.70*** (11.33)	0.65*** (10.24)
LS x Kano State downward NDVI anomaly	…	0.07** (2.12)
LS x Kano State upward NDVI anomaly	…	0.02 (0.66)
ADF	-4.11***	-4.07***
PP	-4.16***	-4.11***
Adj. R^2	0.78	0.80

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.91*** (-3.51)	-0.87*** (-2.99)	-0.94*** (-3.62)	-0.99*** (-3.60)
Kano State urban price first difference	1.01*** (3.96)	1.00*** (3.79)	0.96*** (3.79)	1.15*** (3.81)
Kano State downward NDVI anomaly	…	-2.21 (-0.43)	…	…
Kano State upward NDVI anomaly	…	-1.13 (-0.24)	…	…
Kano State NDVI first difference	…	…	17.24 (1.24)	…
Kano State production first difference	…	…	…	-0.27 (-0.90)
Adj. R^2	0.32	0.28	0.33	0.32
Adj. R^2 difference from Base	…	-0.04	+0.01	0

Figure 4C-12: Kano State rural local rice price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	43.29*** (3.61)	32.65** (2.65)
Kano State urban price	0.73*** (9.57)	0.80*** (10.18)
LS x Kano State downward NDVI anomaly	…	-0.09** (-2.29)
LS x Kano State upward NDVI anomaly	…	0.02 (0.44)
ADF	1.28	-5.41***
PP	-5.00***	-5.41***
Adj. R^2	0.72	0.75

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.59*** (-3.72)	-0.58*** (-3.62)	-0.62*** (-3.78)	-0.59*** (-3.64)
Kano State urban price first difference	-0.09 (-0.56)	-0.13 (-0.81)	-0.08 (-0.45)	-0.09 (-0.56)
Kano State downward NDVI anomaly	…	10.53 (1.48)	…	…
Kano State upward NDVI anomaly	…	-0.09 (-0.01)	…	…
Kano State NDVI first difference	…	…	-17.21 (-0.79)	…
Kano State production first difference	…	…	…	-0.04 (-0.09)
Adj. R^2	0.31	0.31	0.30	0.29
Adj. R^2 difference from Base	…	0	-0.01	-0.02

Figure 4C-13: Kano State rural imported rice price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	7.76* (1.82)	6.84* (1.82)
Kano State urban price	0.85*** (16.69)	0.85*** (16.79)
LS x Kano State downward NDVI anomaly	…	0.09** (2.31)
LS x Kano State upward NDVI anomaly	…	-0.03 (-0.81)
ADF	-5.50***	-5.36***
PP	-5.61***	-5.54***
Adj. R^2	0.86	0.87

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.64*** (-4.20)	-0.65*** (-4.06)	-0.70*** (-4.47)	-0.66*** (-4.23)
Kano State urban price first difference	0.38*** (2.80)	0.39*** (2.71)	0.38*** (2.84)	0.38*** (2.82)
Kano State downward NDVI anomaly	…	-0.94 (-0.30)	…	…
Kano State upward NDVI anomaly	…	-0.14 (-0.03)	…	…
Kano State NDVI first difference	…	…	19.37 (1.41)	…
Kano State production first difference	…	…	…	0.11 (0.69)
Adj. R^2	0.28	0.25	0.29	0.27
Adj. R^2 difference from Base	…	-0.03	+0.01	-0.01

Figure 4C-14: Kano State rural cassava price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	55.66*** (3.18)	60.45*** (3.37)
Kano State urban price	0.42** (2.29)	0.34** (2.29)
LS x Kano State downward NDVI anomaly	…	0.04 (0.32)
LS x Kano State upward NDVI anomaly	…	0.14 (1.37)
ADF	-0.77	-0.78
PP	-3.31***	-3.29***
Adj. R^2	0.11	0.10

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.55*** (-3.13)	-0.51*** (-2.98)	-0.54*** (-3.03)	…
Kano State urban price first difference	0.04 (0.24)	0.06 (0.37)	0.02 (0.14)	…
Kano State downward NDVI anomaly	…	-26.64* (-1.95)	…	…
Kano State upward NDVI anomaly	…	13.79 (0.98)	…	…
Kano State NDVI first difference	…	…	17.34 (0.39)	…
Kano State production first difference	…	…	…	…
Adj. R^2	0.19	0.25	0.16	…
Adj. R^2 difference from Base	…	+0.06	-0.03	…

Figure 4C-15: Kano State rural yams price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	45.63*** (4.85)	47.82*** (5.89)
Kano State urban price	0.38*** (5.70)	0.36*** (5.86)
LS x Kano State downward NDVI anomaly	…	0.18*** (3.84)
LS x Kano State upward NDVI anomaly	…	-0.06 (-1.27)
ADF	-4.33***	-5.60***
PP	-4.42***	-5.59***
Adj. R^2	0.40	0.56

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.58*** (-3.43)	-0.57*** (-3.49)	-0.65*** (-3.83)	-0.60*** (-3.47)
Kano State urban price first difference	0.13 (1.08)	0.18 (1.48)	0.15 (1.22)	0.14 (1.12)
Kano State downward NDVI anomaly	…	12.09* (1.91)	…	…
Kano State upward NDVI anomaly	…	16.37 (1.41)	…	…
Kano State NDVI first difference	…	…	51.65* (1.73)	…
Kano State production first difference	…	…	…	-2.78 (-0.63)
Adj. R^2	0.17	0.24	0.21	0.16
Adj. R^2 difference from Base	…	+0.07	+0.04	-0.01

Figure 4C-16: Kano State rural cowpeas price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	15.42*** (4.57)	15.65*** (4.41)
Katsina State urban price	0.64*** (9.96)	0.64*** (9.19)
LS x Katsina State downward NDVI anomaly	…	0.02 (0.29)
LS x Katsina State upward NDVI anomaly	…	-0.02 (-0.32)
ADF	-4.72***	-4.68***
PP	-4.70***	-4.70***
Adj. R^2	0.68	0.66

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.52*** (-3.69)	-0.51*** (-3.63)	-0.59*** (-4.19)	-0.42*** (-3.08)
Katsina State urban price first difference	0.35*** (3.14)	0.33*** (2.81)	0.34*** (3.14)	0.32*** (3.02)
Katsina State downward NDVI anomaly	…	1.62 (-0.54)	…	…
Katsina State upward NDVI anomaly	…	-0.96 (-0.42)	…	…
Katsina State NDVI first difference	…	…	18.67* (1.89)	…
Katsina State production first difference	…	…	…	0.42** (2.47)
Adj. R^2	0.25	0.23	0.29	0.33
Adj. R^2 difference from Base	…	-0.02	+0.04	+0.08

Figure 4C-17: Katsina State rural maize price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	4.27 (0.75)	5.55 (0.99)
Katsina State urban price	0.86*** (7.60)	0.83*** (7.32)
LS x Katsina State downward NDVI anomaly	…	…
LS x Katsina State upward NDVI anomaly	…	0.12 (1.68)
ADF	-4.35***	-4.56***
PP	-4.31***	-4.51***
Adj. R^2	0.62	0.64

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.35** (-2.18)	-0.39** (-2.30)	-0.37** (-2.42)	-0.35** (-2.15)
Katsina State urban price first difference	0.12 (0.67)	0.03 (0.15)	0.06 (0.37)	0.12 (0.66)
Katsina State downward NDVI anomaly	…	-6.27 (-1.00)	…	…
Katsina State upward NDVI anomaly	…	1.34 (0.61)	…	…
Katsina State NDVI first difference	…	…	23.29** (2.19)	…
Katsina State production first difference	…	…	…	-0.09 (-0.16)
Adj. R^2	0.08	0.07	0.18	0.05
Adj. R^2 difference from Base	…	-0.01	+0.10	-0.03

Figure 4C-18: Katsina State rural millet price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	22.56*** (6.63)	21.55*** (6.58)
Katsina State urban price	0.44*** (6.87)	0.46*** (7.15)
LS x Katsina State downward NDVI anomaly	…	0.13** (2.33)
LS x Katsina State upward NDVI anomaly	…	-0.11** (-2.08)
ADF	-3.97***	-4.49***
PP	-3.83***	-4.33***
Adj. R^2	0.50	0.58

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.46*** (-3.31)	-0.47*** (-3.29)	-0.48*** (-3.39)	-0.45*** (-3.18)
Katsina State urban price first difference	0.17 (1.51)	0.18 (1.51)	0.14 (1.20)	0.17 (1.48)
Katsina State downward NDVI anomaly	…	1.34 (0.44)	…	…
Katsina State upward NDVI anomaly	…	-1.37 (-0.59)	…	…
Katsina State NDVI first difference	…	…	9.84 (0.93)	…
Katsina State production first difference	…	…	…	0.18 (1.00)
Adj. R^2	0.17	0.14	0.17	0.17
Adj. R^2 difference from Base	…	-0.03	0	0

Figure 4C-19: Katsina State rural sorghum price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	19.11** (2.37)	21.19** (2.62)
Katsina State urban price	0.86*** (10.40)	0.83*** (9.86)
LS x Katsina State downward NDVI anomaly	…	0.10* (1.78)
LS x Katsina State upward NDVI anomaly	…	-0.04 (-0.76)
ADF	-3.33***	-3.22***
PP	-4.86***	-5.03***
Adj. R^2	0.70	0.71

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.42*** (-3.37)	-0.38*** (-3.01)	-0.40*** (-3.13)	-0.25** (-2.20)
Katsina State urban price first difference	0.23* (1.90)	0.21 (1.66)	0.21 (1.65)	0.24** (2.28)
Katsina State downward NDVI anomaly	…	5.41 (1.24)	…	…
Katsina State upward NDVI anomaly	…	2.43 (0.73)	…	…
Katsina State NDVI first difference	…	…	11.80 (0.78)	…
Katsina State production first difference	...	…	…	4.66*** (3.92)
Adj. R^2	0.17	0.17	0.16	0.37
Adj. R^2 difference from Base	…	0	-0.01	+0.20

Figure 4C-20: Katsina State rural local rice price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	44.03*** (4.39)	43.74*** (4.24)
Katsina State urban price	0.75*** (10.48)	0.75*** (10.12)
LS x Katsina State downward NDVI anomaly	…	-0.02 (-0.35)
LS x Katsina State upward NDVI anomaly	…	0.01 (0.16)
ADF	-4.44***	-4.50***
PP	-4.40***	-4.45***
Adj. R^2	0.70	0.69

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.28** (-2.23)	-0.27** (-2.10)	-0.28** (-2.20)	-0.28** (-2.21)
Katsina State urban price first difference	0.18 (1.55)	0.19 (1.59)	0.18 (1.51)	0.18 (1.58)
Katsina State downward NDVI anomaly	…	-2.44 (-0.45)	…	…
Katsina State upward NDVI anomaly	…	3.42 (0.81)	…	…
Katsina State NDVI first difference	…	…	3.52 (0.19)	…
Katsina State production first difference	...	…	…	1.97 (1.28)
Adj. R^2	0.06	0.04	0.04	0.08
Adj. R^2 difference from Base	…	-0.02	-0.02	+0.02

Figure 4C-21: Katsina State rural imported rice price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	7.97 (1.25)	10.33 (1.45)
Katsina State urban price	0.85*** (11.55)	0.81*** (9.78)
LS x Katsina State downward NDVI anomaly	…	0.02 (0.28)
LS x Katsina State upward NDVI anomaly	…	0.05 (1.07)
ADF	-4.55***	-4.56***
PP	-4.62***	-4.63***
Adj. R^2	0.74	0.73

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.55*** (-4.16)	-0.56*** (-4.07)	-0.56*** (-4.18)	-0.52*** (-3.92)
Katsina State urban price first difference	0.44** (2.57)	0.40** (2.27)	0.45** (2.64)	0.45*** (2.68)
Katsina State downward NDVI anomaly	…	0.76 (0.16)	…	…
Katsina State upward NDVI anomaly	…	5.37 (1.56)	…	…
Katsina State NDVI first difference	…	…	15.83 (1.06)	…
Katsina State production first difference	...	…	…	-0.87* (-1.82)
Adj. R^2	0.28	0.29	0.28	0.32
Adj. R^2 difference from Base	…	+0.01	0	+0.04

Figure 4C-22: Katsina State rural cassava price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	74.15*** (3.58)	72.53*** (3.58)
Katsina State urban price	0.07 (0.38)	0.07 (0.38)
LS x Katsina State downward NDVI anomaly	…	0.04 (0.40)
LS x Katsina State upward NDVI anomaly	…	0.19** (2.31)
ADF	-5.09***	-5.64***
PP	-5.24***	-5.78***
Adj. R^2	-0.02	0.05

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.76*** (-5.13)	-0.78*** (-4.62)	-0.74*** (-4.89)	-0.76*** (-5.08)
Katsina State urban price first difference	0.27* (1.94)	0.25* (1.76)	0.27* (1.96)	0.27* (1.90)
Katsina State downward NDVI anomaly	…	-3.17 (-0.30)	…	…
Katsina State upward NDVI anomaly	…	-5.59 (-0.77)	…	…
Katsina State NDVI first difference	…	…	28.65 (0.90)	…
Katsina State production first difference	...	…	…	0.26 (0.32)
Adj. R^2	0.39	0.38	0.39	0.38
Adj. R^2 difference from Base	…	-0.01	0	-0.01

Figure 4C-23: Katsina State rural yams price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Levels models

	Base	with interactions
Intercept	29.61** (2.09)	31.20** (2.17)
Katsina State urban price	0.56*** (4.98)	0.53*** (4.61)
LS x Katsina State downward NDVI anomaly	…	0.09 (0.81)
LS x Katsina State upward NDVI anomaly	…	0.10 (0.90)
ADF	-2.56**	-2.75***
PP	-2.58**	-2.75***
Adj. R^2	0.34	0.33

ECM models

	Base	with state NDVI anomalies	with state NDVI differences	with state production differences
Lagged residuals base levels model	-0.21** (-2.56)	-0.19** (-2.19)	-0.21** (-2.50)	-0.25*** (-3.07)
Katsina State urban price first difference	0.06 (0.44)	0.04 (0.31)	0.04 (0.35)	0.07 (0.60)
Katsina State downward NDVI anomaly	…	2.31 (0.28)	…	…
Katsina State upward NDVI anomaly	…	-6.79 (-1.05)	…	…
Katsina State NDVI first difference	…	…	13.96 (0.50)	…
Katsina State production first difference	...	…	…	-0.18** (-2.04)
Adj. R^2	0.09	0.07	0.07	0.15
Adj. R^2 difference from Base	…	-0.02	-0.02	+0.06

Figure 4C-24: Katsina State rural cowpeas price levels and ECM model estimation results

Note: a description of table contents is included below figure 4C-1.

Appendix 4D. Comprehensive Results for the Local Price Model Set

Levels models

	Base	with state interactions	with local region interactions	with both interactions
Intercept	44.07*** (5.90)	44.23*** (5.92)	44.32*** (5.85)	44.32*** (5.85)
Borno State urban price	0.13 (1.05)	0.12 (0.94)	0.11 (0.37)	0.11 (0.91)
LS x Borno State downward NDVI anomaly	…	…	…	0.03 (0.43)
LS x Borno State upward NDVI anomaly	…	0.05 (0.99)	…	…
LS x local region downward NDVI anomaly	…	…	0.03 (0.43)	…
LS x local region upward NDVI anomaly	…	…	0.08 (1.01)	0.04 (0.43)
ADF	-3.96***	-3.82***	-3.89***	-3.89***
PP	-3.30***	-3.36***	-3.34***	-3.34***
Adj. R^2	0.00	0.00	-0.03	-0.03

ECM models

	Base	with state NDVI anomalies	with local NDVI anomalies	with state NDVI first diffs.	with local NDVI first diffs.	with state production first diffs.
Lagged residuals base levels model	-0.46*** (-3.01)	-0.49*** (-3.03)	-0.50*** (-3.52)	-0.83*** (-5.62)	-0.60*** (-4.78)	-0.46*** (-2.96)
Borno State urban price first difference	0.08 (0.65)	0.09 (0.77)	0.11 (1.00)	0.05 (0.56)	0.01 (0.16)	0.07 (0.62)
Borno State downward NDVI anomaly	…	2.84 (0.93)	…	…	…	…
Borno State upward NDVI anomaly	…	0.13 (0.02)	…	…	…	…
Local downward NDVI anomaly	…	…	-6.61** (-2.49)	…	…	…
Local upward NDVI anomaly	…	…	3.98 (1.47)	…	…	…
Borno State NDVI first difference	…	…	…	49.97*** (4.27)	…	…
Local region NDVI first difference	…	…	…	…	36.05*** (4.22)	…
Borno State production first difference	…	…	…	…	…	-0.02 (-0.16)
Adj. R^2	0.20	0.16	0.35	0.51	0.50	0.17
Adj. R^2 difference from base	…	-0.04	+0.15	+0.31	+0.30	-0.03

Figure 4D-1: Damasak, Borno State maize price levels and ECM model estimation results

Note: t-statistics are in parentheses. ***, **, and * denote 1%, 5%, and 10% statistical significance, respectively. Critical values for the ADF and PP statistics associated with stationarity tests of estimated residuals ($\hat{v}_t$) for n=50 are -2.62, -1.95, and -1.60, for 1%, 5%, and 10% levels, respectively. All critical values are provided in Fuller (1996). A statistically significant estimated ECM term ($\hat{\gamma}$) implies cointegration (Banerjee et al. 1986). LS is an abbreviation for "lean season".

Levels models

	Base	with state interactions	with local region interactions	with both interactions
Intercept	30.69*** (3.63)	29.85*** (3.50)	…	…
Borno State urban price	0.31** (2.33)	0.31** (2.36)	…	…
LS x Borno State downward NDVI anomaly	…	0.06 (0.93)	…	…
LS x Borno State upward NDVI anomaly	…	…	…	…
LS x local region downward NDVI anomaly	…	…	…	…
LS x local region upward NDVI anomaly	…	…	…	…
ADF	-2.75***	-3.05***	…	…
PP	-2.66***	-2.98***	…	…
Adj. R^2	0.18	0.18	…	…

ECM models

	Base	with state NDVI anomalies	with local NDVI anomalies	with state NDVI first diffs.	with local NDVI first diffs.	with state production first diffs.
Lagged residuals base levels model	-0.57** (-2.66)	-0.63** (-2.72)	-0.54** (-2.30)	-0.93*** (-3.87)	-0.76*** (-3.46)	-0.57** (-2.55)
Borno State urban price first difference	0.30 (1.52)	0.29 (1.44)	0.33 (1.49)	0.13 (0.68)	0.13 (0.67)	0.26 (0.87)
Borno State downward NDVI anomaly	…	4.51 (1.41)	…	…	…	…
Borno State upward NDVI anomaly	…	-1.13 (-0.19)	…	…	…	…
Local downward NDVI anomaly	…	…	-2.45 (-0.55)	…	…	…
Local upward NDVI anomaly	…	…	-1.87 (-0.45)	…	…	…
Borno State NDVI first difference	…	…	…	40.23** (2.40)	…	…
Local region NDVI first difference	…	…	…	…	29.30* (1.96)	…
Borno State production first difference	…	…	…	…	…	-0.06 (-0.15)
Adj. R^2	0.31	0.31	0.23	0.47	0.41	0.26
Adj. R^2 difference from base	…	0	-0.08	+0.16	+0.10	-0.05

Figure 4D-2: Damasak, Borno State millet price levels and ECM model estimation results

Note: a description of table contents is included below figure 4D-1.

Levels models

	Base	with state interactions	with local region interactions	with both interactions
Intercept	26.04*** (3.32)	27.39*** (3.27)	28.71*** (3.37)	28.71*** (3.37)
Borno State urban price	0.33** (2.29)	0.30* (1.91)	0.27* (1.72)	0.27* (1.72)
LS x Borno State downward NDVI anomaly	…	0.02 (0.52)	…	0.06 (0.97)
LS x Borno State upward NDVI anomaly	…	…	…	…
LS x local region downward NDVI anomaly	…	…	0.06 (0.97)	…
LS x local region upward NDVI anomaly	…	…	-0.01 (-0.20)	-0.07 (-0.90)
ADF	-3.03***	-3.42***	-3.94***	-3.94***
PP	-3.42***	-3.40***	-3.90***	-3.90***
Adj. R^2	0.12	0.10	0.09	0.09

ECM models

	Base	with state NDVI anomalies	with local NDVI anomalies	with state NDVI first diffs.	with local NDVI first diffs.	with state production first diffs.
Lagged residuals base levels model	-0.66*** (-2.97)	-0.66*** (-2.85)	-0.66*** (-3.00)	-0.85*** (-4.00)	-0.72*** (-3.73)	-0.67*** (-2.99)
Borno State urban price first difference	0.22 (1.00)	0.20 (0.86)	0.30 (1.31)	0.11 (0.55)	0.10 (0.48)	0.29 (1.19)
Borno State downward NDVI anomaly	…	2.66 (1.02)	…	…	…	…
Borno State upward NDVI anomaly	…	0.24 (0.05)	…	…	…	…
Local downward NDVI anomaly	…	…	-3.39 (-1.13)	…	…	…
Local upward NDVI anomaly	…	…	3.23 (1.30)	…	…	…
Borno State NDVI first difference	…	…	…	29.20** (2.64)	…	…
Local region NDVI first difference	…	…	…	…	25.40*** (3.10)	…
Borno State production first difference	…	…	…	…	…	-0.04 (-0.70)
Adj. R^2	0.20	0.17	0.23	0.36	0.41	0.19
Adj. R^2 difference from base	…	-0.03	+0.03	+0.16	+0.21	-0.01

Figure 4D-3: Damasak, Borno State sorghum price levels and ECM model estimation results

Note: a description of table contents is included below figure 4D-1.

Levels models

	Base	with state interactions	with local region interactions	with both interactions
Intercept	52.37*** (2.74)	52.78*** (2.69)	52.37*** (2.63)	52.37*** (2.63)
Borno State urban price	0.68*** (4.39)	0.67*** (4.19)	0.67*** (4.15)	0.67*** (4.15)
LS x Borno State downward NDVI anomaly	…	0.01 (0.15)	…	0.04 (0.45)
LS x Borno State upward NDVI anomaly	…	…	…	…
LS x local region downward NDVI anomaly	…	…	0.04 (0.45)	…
LS x local region upward NDVI anomaly	…	…	-0.02 (-0.23)	-0.05 (-0.51)
ADF	-3.41***	-3.41***	-3.51***	-3.51***
PP	-3.29***	-3.30***	-3.38***	-3.38***
Adj. R^2	0.37	0.35	0.33	0.33

ECM models

	Base	with state NDVI anomalies	with local NDVI anomalies	with state NDVI first diffs.	with local NDVI first diffs.	with state production first diffs.
Lagged residuals base levels model	-0.47** (-2.63)	-0.48** (-2.55)	-0.44** (-2.45)	-0.62*** (-3.60)	-0.57*** (-3.49)	-0.44** (-2.48)
Borno State urban price first difference	0.30* (1.94)	0.33* (2.04)	0.26 (1.66)	0.28* (1.98)	0.32** (2.28)	0.26 (1.61)
Borno State downward NDVI anomaly	…	5.79 (0.87)	…	…	…	…
Borno State upward NDVI anomaly	…	2.57 (0.19)	…	…	…	…
Local downward NDVI anomaly	…	…	-4.75 (-0.74)	…	…	…
Local upward NDVI anomaly	…	…	7.18 (1.11)	…	…	…
Borno State NDVI first difference	…	…	…	65.57** (2.55)	…	…
Local region NDVI first difference	…	…	…	…	56.89*** (2.78)	…
Borno State production first difference	…	…	…	…	…	0.70 (0.73)
Adj. R^2	0.17	0.14	0.17	0.31	0.34	0.16
Adj. R^2 difference from base	…	-0.03	0	+0.14	+0.17	-0.01

Figure 4D-4: Damasak, Borno State local rice price levels and ECM model estimation results

Note: a description of table contents is included below figure 4D-1.

Levels models

	Base	with state interactions	with local region interactions	with both interactions
Intercept	65.26** (2.22)	66.47** (2.14)	65.77** (2.08)	65.77** (2.08)
Borno State urban price	0.40** (2.40)	0.39** (2.18)	0.40** (2.17)	0.40** (2.17)
LS x Borno State downward NDVI anomaly	…	0.01 (0.14)	…	0.02 (0.35)
LS x Borno State upward NDVI anomaly	…	…	…	…
LS x local region downward NDVI anomaly	…	…	0.02 (0.35)	…
LS x local region upward NDVI anomaly	…	…	-0.01 (-0.13)	-0.03 (-0.37)
ADF	-2.41**	-2.40**	-2.47**	-2.47**
PP	-2.41**	-2.39**	-2.46**	-2.46**
Adj. R^2	0.13	0.10	0.08	0.08

ECM models

	Base	with state NDVI anomalies	with local NDVI anomalies	with state NDVI first diffs.	with local NDVI first diffs.	with state production first diffs.
Lagged residuals base levels model	-0.30** (-2.17)	-0.32** (-2.15)	-0.27* (-1.90)	-0.36** (-2.65)	-0.33** (-2.48)	-0.29** (-2.06)
Borno State urban price first difference	0.17 (1.22)	0.19 (1.29)	0.15 (1.06)	0.16 (1.16)	0.18 (1.35)	0.13 (0.90)
Borno State downward NDVI anomaly	…	5.59 (0.81)	…	…	…	…
Borno State upward NDVI anomaly	…	5.92 (0.42)	…	…	…	…
Local downward NDVI anomaly	…	…	-2.42 (-0.35)	…	…	…
Local upward NDVI anomaly	…	…	8.19 (1.22)	…	…	…
Borno State NDVI first difference	…	…	…	51.20* (1.93)	…	…
Local region NDVI first difference	…	…	…	…	46.49** (2.12)	…
Borno State production first difference	…	…	…	…	…	0.88 (0.89)
Adj. R^2	0.11	0.07	0.09	0.19	0.21	0.10
Adj. R^2 difference from base	…	-0.04	-0.02	+0.08	+0.10	-0.01

Figure 4D-5: Damasak, Borno State imported rice price levels and ECM model estimation results

Note: a description of table contents is included below figure 4D-1.

Levels models

	Base	with state interactions	with local region interactions	with both interactions
Intercept	16.36** (2.69)	17.98** (2.86)	20.43** (3.33)	20.37*** (3.27)
Katsina State urban price	0.62*** (5.56)	0.58*** (4.98)	0.52*** (4.42)	0.52*** (4.37)
LS x Katsina State downward NDVI anomaly	…	0.08 (1.05)	…	-0.03 (-0.30)
LS x Katsina State upward NDVI anomaly	…	-0.06 (-0.61)	…	…
LS x local region downward NDVI anomaly	…	…	0.13** (2.08)	0.14* (1.76)
LS x local region upward NDVI anomaly	…	…	-0.04 (-0.41)	-0.04 (-0.40)
ADF	-6.10***	-5.79***	-3.60***	-3.54***
PP	-3.10***	-3.08***	-2.85***	-2.83***
Adj. R^2	0.46	0.46	0.50	0.49

ECM models

	Base	with state NDVI anomalies	with local NDVI anomalies	with state NDVI first diffs.	with local NDVI first diffs.	with state production first diffs.
Lagged residuals base levels model	0.04 (0.27)	0.02 (0.12)	0.04 (0.27)	0.02 (0.13)	0.02 (0.13)	0.04 (0.26)
Katsina State urban price first difference	-0.33* (-1.72)	-0.41** (-2.07)	-0.37* (-1.82)	-0.32 (-1.63)	-0.32 (-1.59)	-0.28 (-1.46)
Katsina State downward NDVI anomaly	…	6.56 (1.61)	…	…	…	…
Katsina State upward NDVI anomaly	…	-4.77 (-1.60)	…	…	…	…
Local downward NDVI anomaly	…	…	0.48 (0.17)	…	…	…
Local upward NDVI anomaly	…	…	-2.61 (-0.98)	…	…	…
Katsina State NDVI first difference	…	…	…	2.43 (0.14)	…	…
Local region NDVI first difference	…	…	…	…	3.56 (0.17)	…
Katsina State production first difference	…	…	…	…	…	2.86 (1.57)
Adj. R^2	0.04	0.14	0.01	0.01	0.01	0.08
Adj. R^2 difference from base	…	+0.10	-0.03	-0.03	-0.03	+0.04

Figure 4D-6: Daura, Katsina State maize price levels and ECM model estimation results

Note: a description of table contents is included below figure 4D-1.

Levels models

	Base	with state interactions	with local region interactions	with both interactions
Intercept	-3.30 (-0.57)	-3.87 (-0.67)	-3.19 (-0.51)	-3.19 (-0.51)
Katsina State urban price	0.95*** (8.76)	0.97*** (8.90)	0.96*** (7.80)	0.96*** (7.80)
LS x Katsina State downward NDVI anomaly	…	…	…	…
LS x Katsina State upward NDVI anomaly	…	-0.06 (-1.16)	…	…
LS x local region downward NDVI anomaly	…	…	0.02 (0.31)	0.02 (0.31)
LS x local region upward NDVI anomaly	…	…	-0.05 (-1.04)	-0.05 (-1.04)
ADF	-3.81***	-3.80***	-3.75***	-3.75***
PP	-3.81***	-3.80***	-3.75***	-3.75***
Adj. R^2	0.77	0.77	0.76	0.76

ECM models

	Base	with state NDVI anomalies	with local NDVI anomalies	with state NDVI first diffs.	with local NDVI first diffs.	with state production first diffs.
Lagged residuals base levels model	-0.49** (-2.40)	-0.49** (-2.21)	-0.41* (-1.83)	-0.52** (-2.33)	-0.52** (-2.37)	-0.53** (-2.68)
Katsina State urban price first difference	0.19 (0.67)	0.08 (0.26)	0.08 (0.26)	0.19 (0.62)	0.18 (0.60)	0.25 (0.88)
Katsina State downward NDVI anomaly	…	…	…	…	…	…
Katsina State upward NDVI anomaly	…	-2.62 (-1.65)	…	…	…	…
Local downward NDVI anomaly	…	…	-0.74 (-0.45)	…	…	…
Local upward NDVI anomaly	…	…	-1.79 (-1.08)	…	…	…
Katsina State NDVI first difference	…	…	…	4.19 (0.37)	…	…
Local region NDVI first difference	…	…	…	…	5.09 (0.70)	…
Katsina State production first difference	…	…	…	…	…	0.60 (1.64)
Adj. R^2	0.18	0.25	0.15	0.14	0.14	0.25
Adj. R^2 difference from base	…	+0.07	-0.03	-0.04	-0.04	+0.07

Figure 4D-7: Daura, Katsina State millet price levels and ECM model estimation results

Note: a description of table contents is included below figure 4D-1.

Levels models

	Base	with state interactions	with local region interactions	with both interactions
Intercept	20.02*** (3.46)	18.09*** (3.21)	18.17*** (3.59)	17.92*** (3.48)
Katsina State urban price	0.47*** (4.57)	0.51*** (4.84)	0.49*** (5.12)	0.49*** (5.08)
LS x Katsina State downward NDVI anomaly	…	0.14* (1.80)	…	-0.05 (-0.49)
LS x Katsina State upward NDVI anomaly	…	-0.13* (-1.75)	…	…
LS x local region downward NDVI anomaly	…	…	0.19*** (3.34)	0.21*** (2.70)
LS x local region upward NDVI anomaly	…	…	-0.10 (-1.58)	-0.11 (-1.58)
ADF	-1.21	-3.97***	-3.74***	-3.66***
PP	-2.68***	-2.76***	-2.42**	-2.36**
Adj. R^2	0.36	0.45	0.55	0.54

ECM models

	Base	with state NDVI anomalies	with local NDVI anomalies	with state NDVI first diffs.	with local NDVI first diffs.	with state production first diffs.
Lagged residuals base levels model	0.13 (0.80)	0.03 (0.17)	0.13 (0.80)	0.18 (0.96)	0.14 (0.75)	0.12 (0.78)
Katsina State urban price first difference	-0.15 (-0.85)	-0.18 (-1.02)	-0.24 (-1.24)	-0.14 (-0.76)	-0.15 (-0.79)	-0.14 (-0.77)
Katsina State downward NDVI anomaly	…	7.43* (1.82)	…	…	…	…
Katsina State upward NDVI anomaly	…	-3.36 (-1.26)	…	…	…	…
Local downward NDVI anomaly	…	…	1.77 (0.67)	…	…	…
Local upward NDVI anomaly	…	…	-3.04 (-1.18)	…	…	…
Katsina State NDVI first difference	…	…	…	-9.45 (-0.54)	…	…
Local region NDVI first difference	…	…	…	…	-2.68 (-0.13)	…
Katsina State production first difference	…	…	…	…	…	0.34 (0.80)
Adj. R^2	-0.03	0.06	-0.04	-0.06	-0.07	-0.04
Adj. R^2 difference from base	…	+0.09	-0.01	-0.03	-0.04	-0.01

Figure 4D-8: Daura, Katsina State sorghum price levels and ECM model estimation results

Note: a description of table contents is included below figure 4D-1.

Levels models

	Base	with state interactions	with local region interactions	with both interactions
Intercept	10.23 (0.69)	7.27 (0.47)	8.47 (0.52)	9.01 (0.52)
Katsina State urban price	1.17*** (8.04)	1.22*** (7.83)	1.20*** (7.15)	1.19*** (7.07)
LS x Katsina State downward NDVI anomaly	…	-0.06 (-0.72)	…	-0.08 (-0.77)
LS x Katsina State upward NDVI anomaly	…	-0.06 (-0.69)	…	…
LS x local region downward NDVI anomaly	…	…	-0.01 (-0.17)	0.03 (0.35)
LS x local region upward NDVI anomaly	…	…	-0.05 (-0.62)	-0.05 (-0.61)
ADF	-2.01**	0.92	0.71	-3.05***
PP	-3.26***	-3.46***	-3.25***	-3.05***
Adj. R^2	0.65	0.63	0.63	0.62

ECM models

	Base	with state NDVI anomalies	with local NDVI anomalies	with state NDVI first diffs.	with local NDVI first diffs.	with state production first diffs.
Lagged residuals base levels model	-0.36** (-2.50)	-0.32* (-1.99)	-0.37** (-2.59)	-0.36** (-2.35)	-0.35** (-2.37)	-0.36** (-2.49)
Katsina State urban price first difference	0.18 (0.94)	0.16 (0.81)	0.19 (1.00)	0.19 (0.90)	0.18 (0.86)	0.15 (0.79)
Katsina State downward NDVI anomaly	…	3.43 (0.42)	…	…	…	…
Katsina State upward NDVI anomaly	…	-2.29 (-0.45)	…	…	…	…
Local downward NDVI anomaly	…	…	4.98 (1.09)	…	…	…
Local upward NDVI anomaly	…	…	0.14 (0.03)	…	…	…
Katsina State NDVI first difference	…	…	…	-2.74 (-0.10)	…	…
Local region NDVI first difference	…	…	…	…	0.76 (0.02)	…
Katsina State production first difference	…	…	…	…	…	-1.29 (-0.57)
Adj. R^2	0.11	0.07	0.09	0.09	0.09	0.10
Adj. R^2 difference from base	…	-0.04	-0.02	-0.02	-0.02	-0.01

Figure 4D-9: Daura, Katsina State local rice price levels and ECM model estimation results

Note: a description of table contents is included below figure 4D-1.

Levels models

	Base	with state interactions	with local region interactions	with both interactions
Intercept	-0.32 (-0.02)	0.18 (0.01)	1.11 (0.05)	0.31 (0.01)
Katsina State urban price	0.88*** (6.84)	0.88*** (6.53)	0.87*** (5.93)	0.88*** (5.79)
LS x Katsina State downward NDVI anomaly	…	0.02 (0.29)	…	0.02 (0.21)
LS x Katsina State upward NDVI anomaly	…	0.00 (0.05)	…	…
LS x local region downward NDVI anomaly	…	…	0.01 (0.19)	0.00 (0.02)
LS x local region upward NDVI anomaly	…	…	0.00 (0.06)	0.00 (0.05)
ADF	-3.11***	-3.04***	-3.07***	-3.04***
PP	-3.10***	-3.04***	-3.07***	-3.04***
Adj. R^2	0.57	0.54	0.54	0.53

ECM models

	Base	with state NDVI anomalies	with local NDVI anomalies	with state NDVI first diffs.	with local NDVI first diffs.	with state production first diffs.
Lagged residuals base levels model	-0.36*** (-3.06)	-0.34** (-2.61)	-0.36*** (-3.06)	-0.36*** (-2.92)	-0.36*** (-2.94)	-0.36*** (-3.09)
Katsina State urban price first difference	0.13 (1.15)	0.11 (0.93)	0.12 (1.05)	0.14 (1.13)	0.13 (1.09)	0.13 (1.11)
Katsina State downward NDVI anomaly	…	2.47 (0.32)	…	…	…	…
Katsina State upward NDVI anomaly	…	-2.65 (-0.52)	…	…	…	…
Local downward NDVI anomaly	…	…	4.13 (0.94)	…	…	…
Local upward NDVI anomaly	…	…	0.43 (0.10)	…	…	…
Katsina State NDVI first difference	…	…	…	-3.24 (-0.13)	…	…
Local region NDVI first difference	…	…	…	…	2.71 (0.09)	…
Katsina State production first difference	…	…	…	…	…	-1.55 (-0.73)
Adj. R^2	0.19	0.14	0.16	0.16	0.16	0.17
Adj. R^2 difference from base	…	-0.05	-0.03	-0.03	-0.03	-0.02

Figure 4D-10: Daura, Katsina State imported rice price levels and ECM model estimation results

Note: a description of table contents is included below figure 4D-1.

Levels models

	Base	with state interactions	with local region interactions	with both interactions
Intercept	38.02 (3.41)	44.09 (3.95)	39.51 (3.37)	46.68 (4.07)
Katsina State urban price	0.19 (1.00)	0.07 (0.33)	0.17 (0.80)	0.01 (0.03)
LS x Katsina State downward NDVI anomaly	…	0.20* (2.02)	…	0.23** (2.18)
LS x Katsina State upward NDVI anomaly	…	-0.02 (-0.20)	…	-0.01 (-0.08)
LS x local region downward NDVI anomaly	…	…	0.05 (0.50)	0.10 (0.98)
LS x local region upward NDVI anomaly	…	…	-0.04 (-0.32)	…
ADF	-4.67***	-3.65***	-4.90***	-3.25***
PP	-2.97***	-3.40***	-2.82***	-3.20***
Adj. R^2	0.00	0.07	-0.06	0.07

ECM models

	Base	with state NDVI anomalies	with local NDVI anomalies	with state NDVI first diffs.	with local NDVI first diffs.	with state production first diffs.
Lagged residuals base levels model	-0.28* (-1.82)	-0.39** (-2.63)	-0.32** (-2.18)	-0.38 (-1.41)	-0.38 (-1.61)	-0.28* (-1.78)
Katsina State urban price first difference	0.10 (0.45)	0.07 (0.29)	0.24 (0.99)	0.09 (0.40)	0.11 (0.40)	0.12 (0.48)
Katsina State downward NDVI anomaly	…	13.71** (2.56)	…	…	…	…
Katsina State upward NDVI anomaly	…	-2.13 (-0.56)	…	…	…	…
Local downward NDVI anomaly	…	…	-12.07** (-2.15)	…	…	…
Local upward NDVI anomaly	…	…	-1.44 (-0.32)	…	…	…
Katsina State NDVI first difference	…	…	…	14.35 (0.44)	…	…
Local region NDVI first difference	…	…	…	…	16.86 (0.55)	…
Katsina State production first difference	…	…	…	…	…	0.72 (0.28)
Adj. R^2	0.04	0.19	0.14	0.02	0.02	0.01
Adj. R^2 difference from base	…	+0.15	+0.10	-0.02	-0.02	-0.03

Figure 4D-11: Jibia, Katsina State maize price levels and ECM model estimation results

Note: a description of table contents is included below figure 4D-1.

Levels models

	Base	with state interactions	with local region interactions	with both interactions
Intercept	16.42 (1.47)	16.43 (1.24)	18.12 (1.24)	18.12 (1.24)
Katsina State urban price	0.61** (2.60)	0.61** (2.52)	0.58** (2.10)	0.58** (2.10)
LS x Katsina State downward NDVI anomaly	…	…	…	…
LS x Katsina State upward NDVI anomaly	…	0.00 (0.02)	…	0.01 (0.09)
LS x local region downward NDVI anomaly	…	…	0.03 (0.32)	0.03 (0.32)
LS x local region upward NDVI anomaly	…	…	0.01 (0.09)	…
ADF	-2.94***	-2.94***	-2.87***	-2.87***
PP	-2.96***	-2.96***	-2.91***	-2.91***
Adj. R^2	0.22	0.18	0.14	0.14

ECM models

	Base	with state NDVI anomalies	with local NDVI anomalies	with state NDVI first diffs.	with local NDVI first diffs.	with state production first diffs.
Lagged residuals base levels model	-0.51* (-2.03)	-0.51* (-1.76)	-0.60** (-2.59)	-0.57 (-1.75)	-0.57* (-1.88)	-0.44 (-1.59)
Katsina State urban price first difference	-0.20 (-0.36)	-0.38 (-0.65)	-0.05 (-0.10)	-0.22 (-0.37)	-0.24 (-0.41)	-0.29 (-0.49)
Katsina State downward NDVI anomaly	…	…	…	…	…	…
Katsina State upward NDVI anomaly	…	-3.29 (-1.04)	…	…	…	…
Local downward NDVI anomaly	…	…	-8.56* (-2.14)	…	…	…
Local upward NDVI anomaly	…	…	-3.00 (-0.93)	…	…	…
Katsina State NDVI first difference	…	…	…	7.35 (0.29)	…	…
Local region NDVI first difference	…	…	…	…	9.81 (0.37)	…
Katsina State production first difference	…	…	…	…	…	-0.50 (-0.63)
Adj. R^2	0.19	0.19	0.34	0.14	0.14	0.16
Adj. R^2 difference from base	…	0	+0.15	-0.05	-0.05	-0.03

Figure 4D-12: Jibia, Katsina State millet price levels and ECM model estimation results

Note: a description of table contents is included below figure 4D-1.

Levels models

	Base	with state interactions	with local region interactions	with both interactions
Intercept	31.59*** (4.22)	33.23*** (4.16)	30.42*** (4.06)	31.64*** (4.33)
Katsina State urban price	0.24* (1.86)	0.20 (1.38)	0.23* (1.82)	0.20 (1.56)
LS x Katsina State downward NDVI anomaly	…	0.10 (1.25)	…	0.12 (1.65)
LS x Katsina State upward NDVI anomaly	…	0.03 (0.41)	…	0.05 (0.71)
LS x local region downward NDVI anomaly	…	…	0.20** (2.37)	0.21** (2.61)
LS x local region upward NDVI anomaly	…	…	0.03 (0.42)	…
ADF	-2.95***	-2.56**	-2.06**	-2.25**
PP	-2.61**	-2.69***	-2.31**	-2.41**
Adj. R^2	0.07	0.06	0.17	0.22

ECM models

	Base	with state NDVI anomalies	with local NDVI anomalies	with state NDVI first diffs.	with local NDVI first diffs.	with state production first diffs.
Lagged residuals base levels model	-0.03 (-0.19)	-0.11 (-0.71)	-0.09 (-0.59)	-0.09 (-0.47)	-0.10 (-0.55)	-0.01 (-0.08)
Katsina State urban price first difference	0.00 (0.00)	-0.03 (-0.22)	0.13 (0.78)	-0.03 (-0.16)	-0.04 (-0.24)	-0.02 (-0.11)
Katsina State downward NDVI anomaly	…	7.35* (1.99)	…	…	…	…
Katsina State upward NDVI anomaly	…	-0.88 (-0.35)	…	…	…	…
Local downward NDVI anomaly	…	…	-7.64* (-1.98)	…	…	…
Local upward NDVI anomaly	…	…	-0.57 (-0.20)	…	…	…
Katsina State NDVI first difference	…	…	…	9.11 (0.55)	…	…
Local region NDVI first difference	…	…	…	…	12.56 (0.73)	…
Katsina State production first difference	…	…	…	…	…	-0.39 (-0.97)
Adj. R^2	-0.07	0.01	0.00	-0.10	-0.09	-0.07
Adj. R^2 difference from base	…	+0.08	+0.07	-0.03	-0.02	0

Figure 4D-13: Jibia, Katsina State sorghum price levels and ECM model estimation results

Note: a description of table contents is included below figure 4D-1.

Levels models

	Base	with state interactions	with local region interactions	with both interactions
Intercept	32.63 (1.46)	28.09 (1.21)	36.36 (1.52)	31.19 (1.26)
Katsina State urban price	1.04*** (4.83)	1.10*** (4.85)	1.00*** (4.25)	1.06*** (4.30)
LS x Katsina State downward NDVI anomaly	…	-0.09 (-0.98)	…	-0.09 (-0.86)
LS x Katsina State upward NDVI anomaly	…	-0.03 (-0.35)	…	-0.03 (-0.28)
LS x local region downward NDVI anomaly	…	…	0.06 (0.59)	0.04 (0.40)
LS x local region upward NDVI anomaly	…	…	-0.01 (-0.14)	…
ADF	-0.18	0.07	0.01	-3.32***
PP	-3.88***	-3.99***	-3.85***	-3.98***
Adj. R^2	0.42	0.40	0.39	0.38

ECM models

	Base	with state NDVI anomalies	with local NDVI anomalies	with state NDVI first diffs.	with local NDVI first diffs.	with state production first diffs.
Lagged residuals base levels model	-0.49*** (-2.83)	-0.47** (-2.67)	-0.49** (-2.66)	-0.51*** (-2.77)	-0.50*** (-2.75)	-0.30 (-1.56)
Katsina State urban price first difference	0.18 (0.56)	0.13 (0.42)	0.17 (0.52)	0.16 (0.49)	0.16 (0.49)	-0.14 (-0.42)
Katsina State downward NDVI anomaly	…	13.20 (1.28)	…	…	…	…
Katsina State upward NDVI anomaly	…	-3.15 (-0.43)	…	…	…	…
Local downward NDVI anomaly	…	…	-0.91 (-0.08)	…	…	…
Local upward NDVI anomaly	…	…	-2.61 (-0.30)	…	…	…
Katsina State NDVI first difference	…	…	…	11.06 (0.29)	…	…
Local region NDVI first difference	…	…	…	…	7.79 (0.19)	…
Katsina State production first difference	…	…	…	…	…	-7.41** (-2.08)
Adj. R^2	0.18	0.17	0.12	0.15	0.15	0.27
Adj. R^2 difference from base	…	-0.01	-0.06	-0.03	-0.03	+0.09

Figure 4D-14: Jibia, Katsina State local rice price levels and ECM model estimation results

Note: a description of table contents is included below figure 4D-1.

Levels models

	Base	with state interactions	with local region interactions	with both interactions
Intercept	26.36 (0.99)	25.86 (0.94)	28.59 (0.96)	28.06 (0.92)
Katsina State urban price	0.76*** (4.30)	0.77*** (4.16)	0.74*** (3.66)	0.75*** (3.58)
LS x Katsina State downward NDVI anomaly	…	-0.01 (-0.20)	…	-0.01 (-0.16)
LS x Katsina State upward NDVI anomaly	…	0.01 (0.19)	…	0.02 (0.21)
LS x local region downward NDVI anomaly	…	…	0.02 (0.21)	0.01 (0.18)
LS x local region upward NDVI anomaly	…	…	0.02 (0.23)	…
ADF	-4.06***	-4.13***	-4.07***	-4.10***
PP	-4.05***	-4.12***	-4.07***	-4.09***
Adj. R^2	0.36	0.32	0.32	0.29

ECM models

	Base	with state NDVI anomalies	with local NDVI anomalies	with state NDVI first diffs.	with local NDVI first diffs.	with state production first diffs.
Lagged residuals base levels model	-0.51*** (-3.06)	-0.49*** (-2.85)	-0.51*** (-2.87)	-0.52*** (-2.98)	-0.52*** (-2.93)	-0.38*** (-2.17)
Katsina State urban price first difference	0.15 (0.82)	0.11 (0.58)	0.15 (0.76)	0.15 (0.81)	0.15 (0.80)	0.07 (0.40)
Katsina State downward NDVI anomaly	…	12.14 (1.19)	…	…	…	…
Katsina State upward NDVI anomaly	…	-3.93 (-0.53)	…	…	…	…
Local downward NDVI anomaly	…	…	-2.08 (-0.20)	…	…	…
Local upward NDVI anomaly	…	…	-0.44 (-0.05)	…	…	…
Katsina State NDVI first difference	…	…	…	9.21 (0.25)	…	…
Local region NDVI first difference	…	…	…	…	7.81 (0.20)	…
Katsina State production first difference	…	…	…	…	…	-6.32* (-1.95)
Adj. R^2	0.21	0.20	0.14	0.18	0.18	0.28
Adj. R^2 difference from base	…	-0.01	-0.07	-0.03	-0.03	+0.07

Figure 4D-15: Jibia, Katsina State imported rice price levels and ECM model estimation results

Note: a description of table contents is included below figure 4D-1.

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