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Spatial Market Integration of Food Markets During a Shock: Evidence from Food Markets in Nigeria

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ABSTRACT

This paper uses comprehensive and long time series monthly food price data and a panel dyadic regression framework to evaluate the impact of the COVID-19 pandemic and associated policy responses on spatial market integration across a diverse set of food items in Nigeria. The empirical results reveal several important insights. First, we show that a significant slowdown in the speed of adjustment and price transmission occurred during the pandemic. For some food items, the speed of adjustment and, by implication, spatial market integration weakened by two- to-threefold after the pandemic outbreak. The effect was especially pronounced for perishable food items. Second, lockdown measures and the spread of the pandemic triggered additional dispersion in market prices across markets. For example, lockdown measures were associated with a 5–10 percent reduction in the speed of readjustment toward long-term equilibrium. Third, additional underlying attributes of markets, including lack of access to digital infrastructure and distance between markets, exacerbated impacts associated with the pandemic. For instance, access to Internet service reduced the slowdown in the speed of adjustment caused by the pandemic, but longer distances between market pairs induced greater slowdown in the speed of price transmission. Our findings offer important insights for revitalizing the efficiency of food markets affected by the pandemic. The heterogenous impacts of the pandemic across value chains and markets reinforce the need to properly target post-pandemic recovery interventions and investments. Finally, we offer some insights to reduce the vulnerability of food and market systems to disruptions in future pandemics or similar phenomena that inhibit food marketing and trade.

Keywords: COVID-19 pandemic, Spatial market integration, Panel dyadic regression, Food items, Price transmission, Nigeria.

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1. INTRODUCTION

The COVID-19 pandemic and associated policy responses caused major disruptions to food systems globally (Swinnen and Vos, 2021; Béné, 2020; Barrett, 2020). These disruptions were mostly driven by demand-side contractions and job losses resulting from lockdowns that aimed to reduce the spread of COVID-19. Such disruptions in local and global trade and food systems have major implications for food prices and associated dynamics (Ruan et al., 2021; Narayanan and Saha, 2021). Thus, the pandemic increased volatility in food prices, and such instability can induce detrimental ripple effects on food and nutrition security, migration, and welfare (Reardon et al., 2020b; Ihle et al., 2020).

Additionally, despite variations across countries and value chains, food prices generally increased during the pandemic (Dietrich et al., 2022; Ruan et al., 2021; Narayanan and Saha, 2021). These food market disruptions and the resultant increased volatility and levels of food prices likely had substantial negative effects on both rural and urban households' welfare (Swinnen and Vos, 2021; Béné, 2020; Reardon et al., 2020a). Moreover, closure or disruption of informal food markets, where the poor obtain most of their food, plausibly exacerbated food insecurity among poor households (Barrett, 2020; Amare et al., 2021a).

Although there is evidence that the pandemic had short-term effects on food prices and their volatility, the impact of the pandemic on the functioning and spatial integration of food markets remains less studied. This is particularly the case in Africa, partly because such analysis requires long-term series data that are rarely available. The availability of longer time series monthly price data covering pre-pandemic and pandemic periods can facilitate evaluation of spatial food market integration. In this paper, we used comprehensive monthly food price data (covering 70 months spread across the periods both before and during COVID-19) and a dyadic regression framework to evaluate the impact of the pandemic and associated policy responses on spatial food market integration for a diverse set of food items across Nigeria's 37 states.[1] Nigeria is an interesting case for such an analysis because its pandemic

[1]Nigeria has 36 states and a federal territory (the Federal Capital Territory). For simplicity, we refer to these as 37 states.

and policy responses led to widespread disruptions in the functioning of the country's food value chains (Amare et al., 2021a).

These disruptions reduced consumer and producer welfare throughout the country because most Nigerians rely primarily on markets rather than own production for the foods they consume (Olabisi et al., 2021; Ecker and Hatzenbuehler, 2022). These value chain disruptions had significant impacts on food security, particularly for poorer and vulnerable urban households (Amare et al., 2021a; Abay et al., 2021; Abay et al., 2023). In our efforts to estimate the extent to which pandemic-related disruptions impacted food marketing throughout the country, we selected nine food items (and hence nine value chains) that are widely consumed and traded in Nigeria. Some of these food items are perishable while others are not, a key difference we take into consideration when estimating the extent to which the COVID-19 pandemic and associated lockdowns affected spatial market integration.

The impact of the pandemic and associated policy responses (including mobility restrictions) on spatial market integration are likely to differ across markets with varying exposure to (and severity of) the pandemic. Thus, we explore potential differential effects in spatial market integration for markets and states that experienced relatively high numbers of COVID-19 cases and implemented more stringent lockdown measures relative to those that were less affected. Impacts are also likely to vary across value chains and across markets due to differences in the underlying characteristics of markets. Early evidence from other African countries indicates that value chains for perishable foods experienced greater disruptions than other value chains, including those for cereals, which were relatively resilient (Hirvonen et al., 2021; Mogues, 2020; Narayanan and Saha, 2021). Due to this heterogeneity, we analyze several different types of food items, including perishable, locally traded, and imported products.

Previous studies showed that distance between markets and poor road infrastructure are major impediments to spatial market integration in developing countries (Minten and Kyle, 1999; Dillon and Barrett, 2016; Jones and Salazar, 2021). Similarly, access to digital infrastructure, including mobile phones and the Internet, can facilitate greater spatial market integration (Aker and Mbiti, 2010; Aker, 2010). Indeed, services and market operations that were sufficiently digitalized fared relatively well and remained most resilient to the COVID-19 pandemic (Abay et al., 2020). Following these pieces of evidence, we hypothesized that distance between markets may aggravate the impact of the pandemic, and so generate further price dispersion across markets. Conversely, access to the Internet and digital infrastructure can mitigate the adverse impacts of the pandemic on price transmission by facilitating the flow of information and transactions virtually. To explore these hypotheses, we used Internet penetration data and measures of distance between markets to evaluate potential heterogeneities across these attributes.

The empirical results show that spatial market adjustment in Nigeria weakened significantly following the outbreak of the pandemic. In some cases, price transmission was reduced by between two- and threefold, and these reductions were especially pronounced for perishable food items. We also found that lockdown measures and the spread of the pandemic triggered additional dispersion in prices across markets. For example, lockdown measures were associated with a 5–10 percent reduction in the speed of adjustment associated with deviations from long-run equilibrium. Access to Internet service counteracts the negative speed of adjustment effects associated with the pandemic, but greater distance between markets exacerbates them. These findings, combined with research on the immediate impacts of the pandemic on price levels and volatility, can inform efforts to revitalize the functioning and efficiency of markets affected by the pandemic and similar phenomena in the future that disrupt trade and marketing.

This paper contributes to the broader (and older) literature on spatial market integration analysis as well as to the more recent literature on the impact of the COVID-19 pandemic and policy responses on the functioning of food systems and markets. By evaluating spatial market integration during normal times and during a pandemic, we contribute nuanced empirical evidence to the literature evaluating spatial food market (dis)integration in Africa (Badiane and Shively, 1998; Abdulai, 2000; Asche et al., 2011; Dillon and Barrett, 2016; De Matteis et al., 2021; Heigermoser et al., 2021; Hastings, et al., 2021; Jones and Salazar, 2021; Abay et al., 2022). Despite substantial variations across food items and across time (before and during the pandemic), we show significant spatial market integration prior to the pandemic and that patterns of integration declined after its outbreak. This evidence contributes to the literature on the impact of trade shocks (for example, from food crises, conflicts, or pandemics) on the functioning and efficiency of markets (Hasting et al., 2021; Abay et al., 2022). Our paper also contributes to growing literature on the impact of the pandemic and other shocks on the functioning of food systems and markets (Swinnen and McDermott 2022; Narayanan and Saha, 2021; Mahajan and Tomar, 2021; Salazar et al., 2023). Some studies have estimated the impacts of the pandemic on supply chain disruptions and prices in India (Mahajan and Tomar, 2021). The extent to which the pandemic affected spatial market integration in Africa has not yet been investigated, a gap this paper aims to fill.

The remainder of this paper is organized as follows. Section 2 provides a background on the functioning of food markets in Nigeria. Section 3 presents the data used and associated descriptive results. Section 4 lays out the empirical estimation strategy, Section 5 presents the main results, and the final section offers concluding remarks.

2. BACKGROUND: FOOD SYSTEM AND FUNCTIONING OF FOOD MARKETS IN NIGERIA

This section provides an overview of the modern Nigerian food system and food markets. These details are essential for forming expectations regarding the extent to which spatially disparate food markets are integrated with each other, and which parts of the food system were impacted most acutely by the COVID-19 pandemic and associated policy responses. Food supply, demand, trade, marketing, and disrupting factors are considered sequentially.

2.1. General overview: Food production, consumption, trade, and marketing

Due to its location on the coast of West Africa, proximity to the equator, and its extension north from the coast into the Sahel region, Nigeria has a diverse agroecological landscape. Nigeria's vegetative zones comprise tropical rainforest in the south and several types of savannah land in the north (Amare and Balana, 2023). This mix of tropical and drier rainfed regions, along with the two large river networks associated with the Niger and Benue Rivers, provides conditions for growing a rich variety of food crops. Root crops such as cassava and yams predominate in the southern and central regions, while cereal grains such as millet and sorghum are more commonly grown in the northern regions. Rice is grown along the river networks in many parts of the country (FEWS NET, 2020). Due to their popularity with farmers in Nigeria, several food products are the key focus for development by the Nigerian Federal Ministry of Agriculture and Rural Development (FMARD). Specifically, aquaculture, cassava, cocoa, cotton, cowpeas, maize, oil palm, poultry, rice, sorghum, soybeans, and yams are identified as important crops for meeting domestic and export demand in the most recent FMARD agricultural policy documents—the *Agriculture Promotion Policy* (APP) of 2016–2020 (FMARD, 2016).

Although Nigeria produces a variety of crops and livestock domestically, the country has consistently imported over US$3 billion of dairy, rice, seafood, and wheat annually since 2011 (Ecker and Hatzenbuehler, 2022). Food and other products purchased on international markets outside of Africa are typically imported through ports in the southern coastal region, especially ports near the commercial capital, Lagos. A substantial food trade across land borders also occurs among Nigeria and neighboring countries in West Africa, as shown in the FEWS NET production and trade flow maps for millet and maize (FEWS NET, 2020).

Accordingly, there is high estimated price transmission among urban markets in Nigeria and its West African neighbors (Hatzenbuehler et al., 2017).

Food consumption data in Ecker et al. (2021) show that cereals, starchy tubers (cassava and yams), and plantains comprise a predominant share of the average Nigerian diet on a calorie per day basis. Lower-income households consume more cereals than tuber products, while the converse holds for higher-income households. Higher-income Nigerians also consume greater quantities of fats, fruit, livestock products, sugar, and vegetables than those with the lowest incomes. All Nigerians consume relatively few dairy products compared to international average diets (Ecker et al., 2021). A related but separate factor to income, rural and urban residence, also helps explain variation in food consumption patterns among Nigerian households. The Nigerian Ministry of Budget and National Planning describes an urban-rural divide in the extent of malnutrition (FMBNP, 2016). The empirical investigation of the relationship between malnutrition and urbanization in the Nigerian context by Amare et al. (2020) showed that urbanization is associated with better nutrition outcomes. These results are supported by data in Olabisi et al. (2021), which show that the share of households that reported (in a seven-day recall) consuming five or more products in healthy food groups was about 15 percent higher for urban than rural households.

A more comprehensive explanation of these observed differences in food consumption among Nigerian households with varying income and urban-rural status requires description of the country’s food markets. Data in Olabisi et al. (2021) and Ecker and Hatzenbuehler (2022) show that most Nigerians rely primarily on markets for the foods they consume. Rural households on average meet 31 percent of their food consumption needs with their own production, while this share is only 7 percent among urban households (Olabisi et al., 2021). Markets in both rural and urban areas of Nigeria are provisioned through both local production and trade from either other regions or international markets. Regarding internal trade of domestically produced crops, production of some crops is regionally concentrated due to climatic and other agroecological characteristics (Amare et al., 2021b). This means that some areas have a production surplus that is traded to other parts of the country. For example, the FEWS NET production and trade flow maps show that rice is produced and consumed throughout the country, while cowpeas (white and brown beans) are mainly produced and consumed in northern Nigeria and transported to southern Nigeria for use by households and food processing firms. Cassava-based *garri* is more widely consumed by households in the south than in the north (FEWS NET, 2020).

For the price transmission analysis, we selected nine diverse food items commonly consumed in Nigeria. Some foods are locally produced while others are imported, and some are highly perishable while others are not (Table 1). The selected food items include white and yellow garri, cowpeas (white beans and brown beans), rice (imported and locally produced rice), wheat, and fish (catfish and mudfish). Nigeria is the world's largest cassava producer, and more than 90 percent of cassava produced in Nigeria is consumed locally (Alene et al., 2015). Nigeria is also a major cowpea (brown bean) producer, accounting for an estimated 45 percent of global cowpea production and over 55 percent of the production in Africa (Alene et al., 2015). Moreover, according to the U.S. Department of Agriculture, Nigeria's rice production increased substantially between 2015 and 2020, when annual production reached a high point of over 5 million metric tons. However, Nigeria is still dependent on rice imports, since annual consumption is currently estimated at 7 million metric tons (USDA, 2021). Nigeria is also the largest fish consumer and producer in sub-Saharan Africa, and among the world's largest fish consumers (WorldFish, 2018). Nigeria's aquaculture sector primarily produces freshwater fish, with catfish accounting for 64 percent of aquaculture production in 2015 (WorldFish, 2018).

Table 1: Food items analyzed by category.

	Locally produced	Imported	Perishable	Nonperishable	Processed	Unprocessed
Local rice	✓			✓	✓	
Imported rice		✓		✓		
Wheat		✓		✓		
White *garri*	✓			✓	✓	
Yellow *garri*	✓			✓	✓	
White beans	✓			✓		✓
Yellow beans	✓			✓		✓
Mudfish			✓			✓
Catfish			✓			✓

Source: Author compilation

2.2. Spatial market integration in Nigeria

Although trade flows are essential to understanding how food markets operate in Nigeria, data on traded quantities are rarely available for empirical analysis. Thus, most studies that have analyzed the extent of food market integration have relied solely on price data (Barrett and Li, 2002). Such market integration studies provide estimates of the extent and speed at which prices in spatially distant markets achieve equilibrium. Since it is expected that prices will equilibrate quickly between markets that trade substantially (in terms of quantity) and frequently, market integration studies provide indications of the extent of market equilibrium. Several recent studies have examined price transmission in Nigerian food markets, including assessments of price relationships within states (Hatzenbuehler et al., 2017) and across states (Ikudayisi and Salman, 2014; Hatzenbuehler et al., 2017). The study by Hatzenbuehler et al. (2017) provides a comprehensive overview of the extent to which prices equilibrate in Nigerian staple food markets. In summary, price equilibration occurs rapidly among urban markets within Nigeria, but is slower or does not occur between urban and rural markets, depending on the food product. Generally, in spatially distant markets, prices for more highly traded foods such as imported rice equilibrate faster than prices of foods for which local production plays a larger role in meeting demand (Hatzenbuehler et al., 2017).

Several factors can inhibit food trade, and thus, price equilibration in the modern Nigerian context. Weather fluctuation is an ever-present factor universal to all food-producing regions, and divergences from normal weather patterns, especially drought and excessive heat during the growing season, can cause production shortfalls. Such production declines for food crops can increase the reliance on trade to meet food demand. Hatzenbuehler et al. (2020)

showed that the extent of price equilibration among grain markets in northern Nigeria and Niger is influenced by variation in crop growing conditions. Conflict, unfortunately, has also been a longer-lasting factor that has disrupted livelihoods and economic activity in several regions in Nigeria in the past several decades. The emergence of the COVID-19 pandemic was an additional factor that disrupted food trade in Nigeria, with more widespread effects than weather and conflict, which have more national impacts. The pandemic disrupted markets for food and other goods in Nigeria, as it did around the world, including key food provision programs such as those in schools (Abay et al., 2021; Amare et al., 2021a). The mechanisms through which the pandemic and associated policy responses to reduce viral spread disrupted food marketing were summarized well by Dietrich et al. (2022).[2] These include trade restrictions that limited trade through international ports or land border crossings, restricting transportation by food shipping firms, closing businesses that produce and sell foods, and closing schools and other food service outlets. Dietrich et al. (2022) document that the largest food price effects from COVID-19 policy restrictions were observed for more highly integrated markets. Similarly, distance between markets, road infrastructure, and communication networks are commonly cited as important factors influencing spatial market integration and, hence, price dispersion (Minten and Kyle, 1999; Dillon and Barrett, 2016; Jones and Salazar, 2021; Aggarwal and Narayanan, 2023).

To summarize, the overall food market system in Nigeria prior to the COVID-19 pandemic was generally well integrated, especially among urban areas, but with intermittent localized shocks due to civil conflict, environmental disasters, and/or infrastructure disruptions. Under the status quo for this food market system, a localized food price "shock" would eventually revert to the systemwide equilibrium after a short-run diversion due to one of the factors mentioned that disrupts food price information sharing and/or trade. This food marketing system then underwent a "shared shock" in the COVID-19 pandemic in which food marketing was disrupted on a large enough scale to substantially slow down price equilibration among all markets in the country. Local characteristics such as urbanization and

[2] Both the national and state governments implemented lockdown measures, but substantial variation arose in the number of documented COVID-19 cases and the length and degree of enforcement across states. Since food markets across states, especially those in urban marketing hubs, were closely linked with each other in the pre-pandemic period (Hatzenbuehler et al., 2017), limiting transportation and other services due to lockdowns in some states had negative effects on food supply and marketing in other states (Narayanan and Saha, 2021; Mahajan and Tomar, 2021).

communications infrastructure plausibly impacted the extent to which local price shocks persisted or were equilibrated by arbitrage with other markets. Given this general characterization of the Nigerian food market system, our approach is to first estimate models that account for the COVID-19 pandemic effects on Nigerian food market integration alone. We then supplement these base models with information on distance between markets and Internet connectivity to discern whether these variables dampened or exacerbated the pandemic's effects.

3. DATA AND DESCRIPTIVE STATISTICS

3.1. Data sources

We used a long time series of monthly food price data obtained from the Nigerian National Bureau of Statistics (NBS). The NBS reports that these prices are collected from all 774 local government areas across all 36 states and the Federal Capital Territory (FCT) from over 10,000 respondents and locations and reflect actual retail prices. These retail prices are gathered by NBS staff at several markets in each state on a weekly or bi-weekly basis, depending on the food item. These weekly or biweekly prices are then averaged across markets and weeks to obtain a statewide average monthly price for each food item (Nwaboku, 2006)[3]. Thus, the price series used in this study are average state-level monthly prices, as we conducted market integration across states. We compiled data from the pre-COVID-19 period through the pandemic period for nine food items across all 36 states and the FCT. The dataset comprised prices over the 70-month period from January 2016 to October 2021. The prices from January 2016 to March 2020 (50 months) capture trends in prices for the pre-COVID-19 period, while those from March 2020 to October 2021 (20 months) represent the pandemic period trends.

To capture the spread and severity of the pandemic, we obtained data on the number of COVID-19 cases from the Nigerian Centre for Disease Control (NCDC, 2020). We used the confirmed COVID-19 cases up to the end of October 2021. The stringency of government lockdown measures was captured based on policy announcements by the federal and state governments of Nigeria (FGN, 2020a, 2020b; NCDC, 2020; Amare et al., 2021a). We focused on the strictest mobility restrictions by defining an indicator variable that takes a value of 1 for those states that introduced lockdown measures, and a value of 0 for those states that did not. We note that these mobility restrictions and lockdown measures lasted for a few months in 2020. However, they may have structurally affected trade links and flows and may have inhibited price transmission across markets even after these restrictions were lifted, since alternative marketing arrangements may have been established due to the disruption that persisted for some time.

[3] The average monthly prices are available at *https://nigerianstat.gov.ng/elibrary/read/1241203*.

We extracted data on Internet access from Collins Bartholomew, a digital mapping service that compiles mobile network data provided by national mobile operators through the Global System for Mobile Communications Association (GSMA). These data are widely used in studies evaluating the impact of access to the Internet or mobile technologies in various settings (Manacorda and Andrei, 2020). These are granular data on mobile coverage for three generations of mobile technologies: 2G, 3G, and 4G. 2G mobile technologies support voice calls and short message services (SMS), while 3G and 4G enable mobile broadband Internet in addition to voice calls and SMS. For this study, we focused on access to 3G and 4G network coverage. Specifically, we computed a population-weighted variable that captures the share of population in each state living in an area with access to Internet service. We computed this variable at the baseline, or pre-pandemic period. We also employed a network analysis and measured distance from each state capital to the remaining 36 state capitals, using the Open-Source Routing Machine, to examine the implication of distance for market integration.

3.2. Descriptive statistics

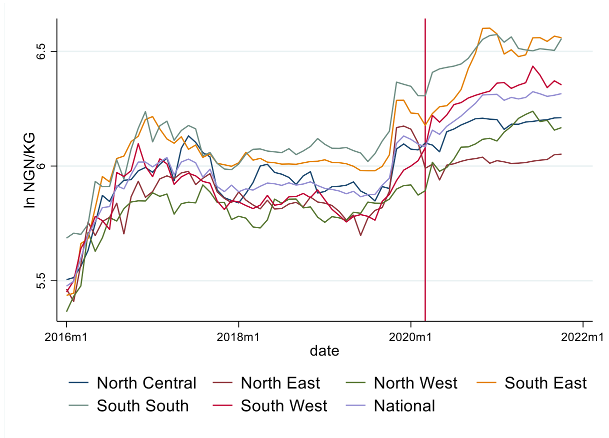
Based on the above information about states and markets, we created a dyadic dataset that links each individual state to the remaining 36 states. We note that such an approach assumes that trade may happen across all states. Such an assumption may sometimes sound implausible given that existing infrastructure likely defines trade patterns, but we followed this more comprehensive approach to avoid imposing some unnecessary assumptions and structure into the data. Furthermore, tradability may not necessarily trigger competitive market equilibrium and spatial market integration (Barrett and Li, 2002). To display price trends graphically, we used averages across geopolitical zones to show the evolution of food prices and market price dispersion before and after the outbreak of the pandemic.[4] Nigeria is divided into six geopolitical regions: North Central, North East, North West, South East, South South, and South West. Trade and spatial market integration between markets and states in similar geopolitical zones is likely to be stronger than across markets in different zones. Thus, the average for a geopolitical zone is expected to represent the general trends for states in the geopolitical zone.

[4] The actual estimation is conducted using state-level prices, not those aggregated to geopolitical zones.

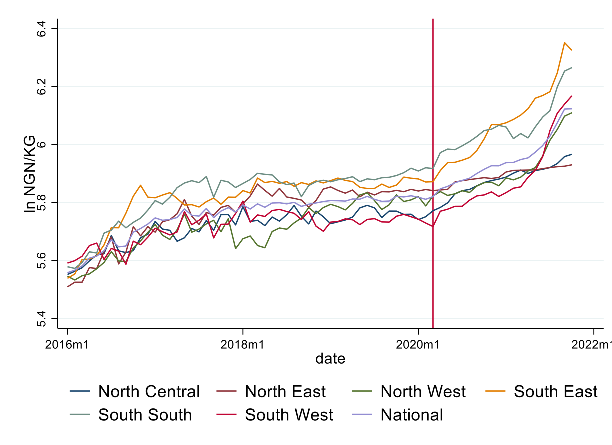
The plots in Figure 1 show the evolution of prices for selected food items for each geopolitical zone (additional figures are available in the Appendix). Three important patterns are worth highlighting. First, for most food items, prices before the pandemic were relatively stable. Second, most food items experienced a short-lived price dip immediately after the outbreak of the pandemic, after which most food items saw significant price increases. Third, most of the plots suggest that geopolitical regions experienced a significant increase in price dispersion across geopolitical zones that began immediately after the outbreak of the pandemic, suggesting a weakening of price transmission during the pandemic. Our econometric estimation explores these patterns further to determine whether these changes and increases in prices can be attributed to the spread of COVID-19 and associated mobility restrictions.

Figure 1: Trends in prices for select food items.

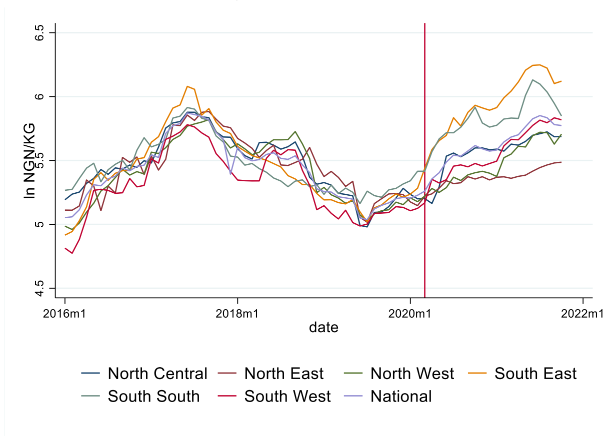
a) Imported Rice



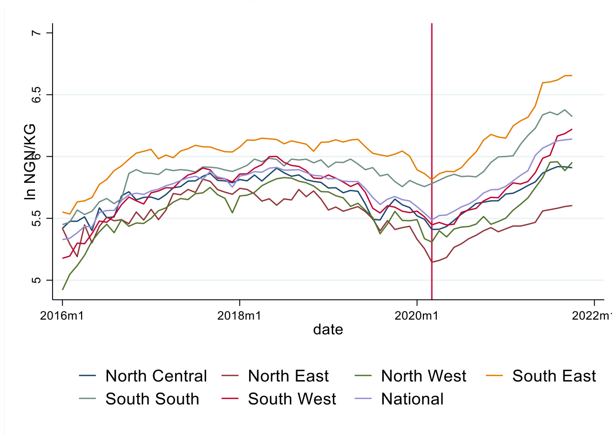
b) Wheat



c) Yellow *Garri*



d) White Beans



Source: Analysis of NBS; covers the period January 2016 to October 2021.

Table 2 provides aggregated summary statistics based on the above information, as well as differences in prices pre-COVID-19 and during the pandemic. Significant increases in prices occurred for all food items, ranging from 3 percent to 42 percent, after the outbreak of the pandemic. For example, prices of imported and locally produced rice increased by 41 percent and 36 percent, respectively. Similarly, the price of wheat increased by 21 percent, white *garri* by 26 percent, and yellow *garri* by 21 percent. The last rows in Table 2 show that, on average, states experienced 6,598 COVID-19 cases. About 14 percent of the population had access to Internet service (3G and 4G network coverage). Nigeria is a large country, and distances between state capitals are substantial, averaging about 500 kilometers. Almost one-half (44 percent) of the states-imposed lockdown restrictions in the period March 28 through May 15, 2020 (see also Amare et al., 2021a).

Table 2: Descriptive statistics and price coefficient of variation.

	Pooled average		Pre-COVID-19		During the pandemic		Difference % test (during the pandemic & pre-COVID-19)
Food items	Mean	SD	Mean	SD	Mean	SD	
Imported rice	415.47	106.74	372.22	68.32	523.61	108.83	40.67***
Local rice	312.52	79.27	283.14	59.62	385.98	74.52	36.32***
Wheat	670.60	101.94	631.99	67.98	767.13	108.53	21.38***
White *garri* (Cassava)	216.76	72.60	201.59	63.26	254.68	80.25	26.33***
Yellow *garri* (Cassava)	244.61	77.49	230.78	70.54	279.18	83.13	20.97***
Brown bean (Cowpea)	352.40	106.72	347.46	82.86	364.75	150.03	4.98*
White bean (Cowpea)	317.80	97.30	310.01	75.02	337.29	136.22	8.80**
Mudfish	1015.39	205.33	998.87	183.63	1056.68	246.85	5.79*
Catfish	1022.29	208.18	991.18	167.11	1100.06	271.07	10.99**
Other covariates							
COVID-19 cases in each state					6598.12	15513.34	
COVID-19 cases per population (%)					1.60	3.40	
State implemented lockdown (%)					44.00	50.00	
Distance between state capitals (km)	493.56	248.70					
¾G mobile coverage (%)	14.00	12.00					

Source: Nigerian Bureau of Statistics (NBS); the Nigerian Centre for Disease Control (NCDC); and Global System for Mobile Communications Association (GSMA).

Note: Prices are in Nigerian naira. Currently, 1 US dollar is worth of about 415 Nigerian naira.

4. Empirical Estimation Strategy

Our empirical strategy began with several prerequisite tests to determine the stationarity properties of the price series and builds on previous theories on spatial market integration. According to the Law of One Price, spatial integration of markets holds when prices of homogenous and tradable commodities across multiple markets share similar long-run patterns (González-Rivera and Helfand, 2001). In this context, price differences (across locations) above the cost of transporting a tradable commodity should encourage further trade and arbitrage, which cause price equilibration. Thus, price differences that exceed the cost of transportation in spatially disparate markets are only likely to persist until market actors react to these deviations.

Quantifying such short-term adjustments and long-run price transmission mechanisms requires understanding of spatial and temporal dynamics of price differences, as well as their time series properties. For this purpose, we first assessed the time series properties of the price series for each food item. This entailed testing whether the price series differences are stationary and, hence, exhibit long-run cointegration (Dickey and Fuller, 1981). We implemented these tests for the pooled sample as well as separately for the periods before and during the pandemic. Once we confirm that price differences (across states) for each food item cointegrate (that is, the differences are stationary), it is possible to estimate and interpret short-run adjustment coefficients. For testing stationarity of logarithmic price differentials prior to (and during) the pandemic, we employed alternative panel unit root tests (Im, Pesaran, and Shin [IPS], 2003; Pesaran, 2007). Specifically, we implemented the Pesaran panel unit root test in the presence of cross-section dependence (Pesaran, 2007). This test is called the cross-sectionally augmented IPS (CIPS) test, which is like the IPS and is a test of the joint null of a unit root against the alternative of at least one stationary series in the panel. We also provide disaggregated trends in differences in logarithmic prices across markets (Figure A2–A4), which broadly show stationary processes.

Given the period covered in this study, we were particularly interested in characterizing short-run adjustment patterns rather than long-run price transmission. For understanding the impact of the pandemic on spatial market integration, we built on previous market integration studies and models that explicitly allow for transaction costs and associated frictions across markets (Ravallion, 1986; Barrett and Li, 2002; Van Campenhout, 2007;

Goodwin et al., 2011; Hastings et al., 2021). The COVID-19 pandemic and associated mobility restrictions significantly increased transport and transaction costs. To explicitly account for this, let $Y_{ijt} = \ln(P_{it}) - \ln(P_{jt})$ be the differences in logarithmic prices across markets *i* and *j* for each month *t*. Since the analysis is the same for each food item, we suppress item subscripts. Before modeling the impact of the pandemic on spatial market adjustments, we first characterize the pre- and during-pandemic spatial price adjustment using the following dyadic panel regression:

$$\Delta Y_{ijt} = \beta Y_{ijt-1} + \delta_{ij} + \varepsilon_{ijt} \quad (1)$$

where Δ is the first-difference operator; Y_{ijt-1} captures lagged logarithmic price differences between states; δ_{ij} stands for dyad-specific fixed effects; and ε_{ijt} captures other unobservable factors that explain potential temporal dynamics in prices. Assuming a stationary time series process (in Y_{ijt}), β measures the speed of adjustment to long-run equilibrium prices or simply the response of ΔY_{ijt} to deviations from the equilibrium. In the presence of significant adjustment to the equilibrium, we expect β to fall between negative one and zero ($-1 < \beta < 0$).

We estimated the empirical specification in equation (1) separately for the pre- and during-pandemic periods. This helps determine if structural changes occurred in the spatial market integration and speed of adjustment to long-run equilibrium without imposing many structural and parametric assumptions. We also parametrically test for heterogeneity in the speed of adjustments across time using the following empirical (difference-in-difference) specification:

$$\Delta Y_{ijt} = \beta_0 Y_{ijt-1} + \gamma Pandemic_t + \beta_1 Y_{ijt-1} * Pandemic_t + \delta_{ij} + \epsilon_{ijt} \quad (2)$$

where all terms except $Pandemic_t$ are as defined above. $Pandemic_t$ is an indicator variable assuming a value of 1 for the period during the pandemic, and 0 otherwise. The parameter β_1 captures the additional change in the speed of adjustment during the pandemic. Thus, if the COVID-19 pandemic had a limited effect on spatial market integration, β_1 would be statistically insignificant. On the other hand, if the pandemic reduced spatial market integration, β_1 would be positive and statistically significant.

However, the pandemic may have reduced spatial market integration nonlinearly and heterogeneously across states experiencing varying intensity in the spread of COVID-19 or associated policy responses. Thus, we also estimated the following more flexible specification that encompasses additional heterogeneity across states with varying exposure to the pandemic and associated lockdown measures. We implement the following empirical specifications:

$$\Delta Y_{ijt} = \alpha_0 Y_{ijt-1} + \gamma_1 Pandemic_t + \alpha_1 Y_{ijt-1} * Pandemic_t + \alpha_2 Y_{ijt-1} * Pandemic_t * Covid_{ij} + \delta_{ij} + \omega_{ijt} \quad (3)$$

$$\Delta Y_{ijt} = \delta_0 Y_{ijt-1} + \gamma_2 Pandemic_t + \delta_1 Y_{ijt-1} * Pandemic_t + \delta_2 Y_{ijt-1} * Pandemic_t * lockdown_{ij} + \delta_{ij} + \varphi_{ijt} \quad (4)$$

where terms also in models (1) and (2) are as defined before. $Covid_{ij}$ stands for the number of COVID-19 cases per population (percent) in each state. $lockdown_{ij}$ represents a categorical variable assuming a value of 1 if one state introduced a lockdown during the pandemic, 2 if both states introduced lockdowns, and 0 if neither state introduced lockdowns. The parameters associated with the interaction terms (between lagged price differentials and $Covid_{ij}$ or $lockdown_{ij}$) are introduced to capture the differential speed of adjustment across states/market pairs with varying level of exposure to the pandemic, as measured by either the number of recorded cases or associated lockdown measures. This is intuitive because states and markets in Nigeria experienced varying levels and degrees of exposure to the pandemic (Amare et al., 2021a). Thus, α_2 and δ_2 capture potential heterogeneity in the speed of adjustment associated with market pairs experiencing different degrees of pandemic severity. If the spread of the pandemic, and hence associated lockdown measures, had negligible effects on spatial market integration, α_2 and δ_2 would be statistically insignificant. However, if the spread of the pandemic or associated lockdown weakened spatial market integration, and hence slowed the speed of adjustment, α_2 and δ_2 would be greater than zero and statistically significant. We note that the spread of the pandemic is strongly correlated with public policy responses, including lockdown and mobility restrictions. Thus, we did not control for both COVID-19 cases and lockdown indicators in the same specification. Rather, we use them interchangeably as spelled out in equations (3)– (4), partly to probe the robustness of our results.

We further extended the empirical specifications in equation (2) to uncover potential heterogeneities and mechanisms that may moderate the impact of the pandemic across different markets. For example, preexisting and underlying attributes of states and markets (such as distance between markets and access to Internet infrastructure) may also trigger heterogeneity in spatial market integration and speed of adjustment. To explore these hypotheses, we expand the empirical specification in equation (2) to capture the potential heterogeneities related to these attributes.

5. RESULTS AND DISCUSSION

In this section, the first set of results explores the presence of long-run spatial integration of local food markets by testing for stationarity in price differentials across markets. The next set evaluates the speed of adjustment and potential changes caused by the COVID-19 pandemic and associated lockdown measures.

5.1. Stationarity test

Following the steps outlined in Section 4, we began by evaluating the stationarity of logarithmic price differentials $(Y_{ijt} = \ln(P_{it}) - \ln(P_{jt}))$ for each food item. We performed a range of panel and market pair-specific unit root tests using CIPS unit root test. We implemented CIPS unit root tests separately for the pooled, pre-pandemic, and pandemic period samples. Under the null hypothesis of stationarity or convergence in the price differential, a failure to reject the null hypothesis would indicate no long-run relationship between market prices. The CIPS test results in Table 3 indicate that the unit root test statistic values for all food items are above the critical value at the 1 percent significance level. Thus, these results imply rejection of the null of panel unit root hypothesis, suggesting that a statistically significant proportion of the price differences across market pairs are stationary. Overall, our results generally show the presence of (long-run) market integration. The disaggregated plots in Figures A2–A4 also broadly confirm that for most products and market pairs, differences in logarithmic prices are likely to follow a stationary process.[5] This finding is consistent with previous evidence that showed significant cointegration, and hence robust long-run price transmission, across Nigerian markets (Ikudayisi and Salman, 2014; Hatzenbuehler et al., 2017; Hatzenbuehler et al., 2020). After documenting evidence of stationarity of price differentials, and hence cointegration across markets, the next step was to estimate the speed of adjustment and potential changes caused by the COVID-19 pandemic and associated lockdown measures. Effectively, once we confirmed co-integration and long-run price transmission, our next step was to characterize short-run adjustment patterns and parameters.

[5] These are aggregated means of logarithmic price differentials across all possible market combinations.

Table 3: Pesaran panel unit root test.

	CIPS test statistic value (Pooled)	CIPS test statistic value (Pre-pandemic)	CIPS test statistic value (During the pandemic)
Imported rice	-5.377	-5.944	-5.492
Locally produced rice	-5.541	-5.512	-5.468
Wheat	-5.304	-5.587	-5.259
Brown bean	-5.378	-5.562	-5.478
White bean	-5.475	-6.049	-5.559
White *garri*	-5.375	-5.531	-5.427
Yellow *garri*	-5.540	-5.552	-5.087
Mudfish	-4.832	-5.384	-5.283
Catfish	-5.286	-5.573	-4.785

Source: Nigeria Bureau of Statistics (NBS).
Note: CIPS = Cross-sectionally augmented Im, Pesaran, and Shin.

5.2. Spatial market interdependence and adjustment pre-pandemic and during the pandemic

The next part of the analysis entailed estimating the speed of adjustment and associated changes caused by the COVID-19 pandemic and associated policy measures. Table 4 reports speed-of-adjustment coefficients associated with market responses to deviations from long-run equilibrium. These adjustment coefficients can be interpreted as percentage adjustments associated with deviations from long-run equilibrium. Panel A of Table 4 provides the estimated speed-of-adjustment parameters for local and imported rice; Panel B shows those for wheat; Panel C shows those for beans (white and brown); Panel D shows those for *garri* (white and yellow); and Panel E shows corresponding estimates for catfish and mudfish. Columns 1 and 5 include results for speed-of-adjustment parameters for the pooled sample, while the other columns provide results for alternative variants of models associated with either the pre-pandemic or pandemic period.

The parameter estimates in Table 4 provide several important insights. First, despite some variations across food items and value chains, there is compelling evidence of spatial market integration, implying consistent adjustment to long-run equilibrium. However, marked differences exist across food items. For example, the speed-of-adjustment parameters associated with the pooled data (columns 1 and 5) range from -0.38 for local rice to -0.09 for catfish. This implies that on average local rice prices adjust 38 percent of disequilibrium in one month while catfish prices correct only 9 percent of disequilibrium in one month. The relatively higher speed of adjustment associated with rice, which is relatively more traded than catfish, is consistent with results from previous studies in Nigeria (Hatzenbuehler et al., 2017). However, the magnitudes are significantly higher than corresponding estimates from conflict-affected settings in Africa (Hastings et al., 2021). To provide a clearer description of these differences in adjustments in deviations, we computed half-life coefficients. These half-life coefficients measure the time it takes market actors to correct one-half of the deviations from equilibrium. They are calculated via the equation $HC = \frac{\ln(0.5)}{\ln(1-\hat{\alpha})}$ (Goodwin and Piggott, 2001) (see full set of estimates in Table A1 in the Appendix). These coefficients show that the time needed for correcting one-half of the deviations from equilibrium has a wide range, ranging from 1.5 months for local rice to 14.0 months for catfish. These staggering differences are likely driven by the nature of the value chains and the role of trade in these value chains. For example, nonperishable items like rice and wheat are easily traded across regions and over time and states, while perishable animal-source foods may not be widely or frequently traded across long distances in the absence of cold chain technology and infrastructure. If food items are not widely or frequently traded across states and regions, the speed-of-adjustment coefficients are more likely to be small.

Second, the parameters in Table 4 clearly show significant variations in the speed of adjustment between the pre-pandemic and pandemic periods. Comparing the size of the speed-of-adjustment coefficients for the pre-pandemic period (columns 2 and 6) with those for the pandemic period (columns 3 and 7) reveals that spatial market integration weakened substantially during the pandemic. This observation is reflected in the lower adjustment coefficients or larger half-time coefficients. In particular, the coefficient associated with the interaction terms between lagged differences and time dummies is positive and statistically significant for all food items (columns 4 and 8). The differences in the speed of adjustment, and thus spatial market integration across time (pre-pandemic and during the pandemic), vary significantly across value chains and food items. For example, the pre-pandemic and during-pandemic differences for yellow and white *garri* appear negligible, while these differences are about fourfold greater for mudfish and fivefold greater for catfish. During the pandemic the price adjustment for mudfish and catfish was very slow, such that correcting one-half of the deviations from equilibrium prices was estimated to take 6–14 months (Table A1).

Similarly, the speed of adjustment, and thus spatial market integration, during the pandemic weakened by about twofold for beans (both white and brown). For example, on average local white bean prices adjusted 37 percent of disequilibrium in one month per-pandemic, versus 17 percent during the pandemic. Similarly, on average brown bean prices corrected 48 percent of disequilibrium in one month pre-pandemic but only 18 percent during the pandemic. These results suggest that for some value chains, the pandemic caused significant and persistent disruptions to spatial market integration. This is consistent with early evidence showing differential impacts of the pandemic across different value chains (Hirvonen et al., 2021). For example, several studies showed that value chains for perishable products were significantly disrupted by the pandemic, while other value chains, including cereals, were relatively resilient (Swinnen and Vos, 2021; Hirvonen et al., 2021; Mogues, 2020).

Table 4: Speed-of-adjustment parameters: Pre-pandemic and during the pandemic.

Panel A:	Local Rice				Imported Rice			
	Pooled	Pre COVID-19	During the pandemic		Pooled	Pre COVID-19	During the pandemic	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Y_{ijt-1}	-0.376***	-0.462***	-0.379***	-0.413***	-0.277***	-0.442***	-0.313***	-0.382***
	(0.006)	(0.007)	(0.008)	(0.007)	(0.005)	(0.007)	(0.007)	(0.007)
Pandemic				-0.005***				0.005***
				(0.002)				(0.002)
Pandemic*Y_{ijt-1}		`		0.109***				0.204***
				(0.006)				(0.007)
Panel B:	Wheat							
Y_{ijt-1}	-0.243***	-0.334***	-0.140***	-0.310***				
	(0.004)	(0.006)	(0.007)	(0.005)				
Pandemic				0.003***				
				(0.001)				
Pandemic*Y_{ijt-1}				0.183***				
				(0.007)				
Panel C:	White Bean				Brown Bean			
Y_{ijt-1}	-0.218***	-0.366***	-0.165***	-0.334***	-0.237***	-0.479***	-0.183***	-0.418***
	(0.004)	(0.006)	(0.007)	(0.005)	(0.007)	(0.011)	(0.006)	(0.010)
Pandemic				0.006***				-0.004**
				(0.001)				(0.002)
Pandemic*Y_{ijt-1}				0.162***				0.242***
				(0.005)				(0.009)
Panel D:	Yellow *Garri*				White Garri			
Y_{ijt-1}	-0.220***	-0.335***	-0.342***	-0.280***	-0.204***	-0.312***	-0.284***	-0.260***
	(0.005)	(0.005)	(0.008)	(0.005)	(0.004)	(0.006)	(0.007)	(0.006)
Pandemic				-0.012***				-0.005**
				(0.003)				(0.002)
Pandemic*Y_{ijt-1}				0.148***				0.137***
				(0.007)				(0.007)
Con	-0.006***	-0.002***	-0.030***	-0.002**	-0.010***	-0.009***	-0.028***	-0.007***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)
Panel E:	Catfish				Mudfish			
Y_{ijt-1}	-0.091***	-0.191***	-0.067***	-0.155***	-0.201***	-0.344***	-0.132***	-0.289***
	(0.003)	(0.005)	(0.004)	(0.004)	(0.005)	(0.006)	(0.009)	(0.005)
Pandemic				0.006***				0.007***
				(0.001)				(0.002)
Pandemic*Y_{ijt-1}				0.128***				0.207***
				(0.004)				(0.006)
No. observations	47804	34447	13357	47804	47804	34447	13357	47804

Source: Nigeria Bureau of Statistics (NBS) and Nigerian Centre for Disease Control (NCDC).

Note: Standard errors, clustered at market/state pair level, are given in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5.3. The effect of lockdown measures and COVID-19 intensity on speed of adjustment

The next part of the analysis focuses on estimating whether exposure to lockdown measures or the number of recorded COVID-19 cases induced additional slowdown and heterogeneity in the speed of adjustment. Lockdown measures involved the closure of businesses and restrictions on citizens' mobility. These mobility restrictions were enforced in a decentralized manner, and substantial variation arose in the extent of lockdown measures across states (Amare et al., 2021a). Most of the measures were introduced immediately after Nigeria detected a few hundred cases and the WHO declared the outbreak a global pandemic in March 2020. Most remained in place for a few months. However, although short-lived, the disruptive effects of restrictions on the functioning and efficiency of markets can be long-lasting, as observed in Figure 1.

The results in Table 5 show further evidence that spatial market integration decreased during the pandemic, and that lockdown measures were associated with reductions in spatial market integration. The coefficients for the interaction terms between the speed of adjustment during the pandemic and markets that implemented lockdown measures are positive and statistically significant. These results imply that states that implemented lockdown measures experienced a significantly greater reduction in spatial market integration relative to those states that did not. However, significant differences appear across food items, as reflected by the sign and significance of the estimated α_3 and δ_3 coefficients. For example, lockdown measures reduced spatial market integration for imported rice, while local rice remained unaffected. The intensity of the lockdown was controlled by including an additional indicator variable equal to 2 when both markets in a pair introduced lockdown measures (last row of each panel). The estimates for the models that account for lockdown intensity show that the disruptions in market integration were larger when both states in a pair-imposed lockdown measures than when only one market did. This is intuitive because mobility restrictions in both states can lead to a total stoppage of trade flows between states.

We find that lockdown measures are associated with an estimated 5–10 percent additional reduction in the speed of adjustment for prices of imported rice. For example, states that imposed lockdown measures experienced about 10 percent reduction in imported rice adjustments to equilibrium in one month. We note that these are meaningful effects given that these monthly effects are likely to accumulate over time. However, the results also highlight important variations in susceptibility and resilience across value chains. Local value chains appear to be more resilient to lockdowns and associated mobility restrictions than those for imported foods. For example, lockdown measures were found to have only a negligible effect on the speed of adjustment for local rice and catfish.

Table 5: Effect of lockdown measures on spatial market integration.

	Rice		Wheat	Beans		*Garri*		Fish	
	Imported	Local	Wheat	Brown	White	Yellow	White	Mudfish	Catfish
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Y_{ijt-1}	-0.385***	-0.413***	-0.310***	-0.418***	-0.334***	-0.280***	-0.260***	-0.290***	-0.155***
	(0.007)	(0.007)	(0.005)	(0.010)	(0.005)	(0.005)	(0.006)	(0.005)	(0.004)
Pandemic	0.005***	-0.005***	0.003***	-0.005**	0.006***	-0.012***	-0.005**	0.007***	0.006***
	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)	(0.003)	(0.002)	(0.002)	(0.001)
Pandemic*Y_{ijt-1}	0.163***	0.102***	0.175***	0.229***	0.150***	0.127***	0.124***	0.196***	0.125***
	(0.009)	(0.009)	(0.011)	(0.010)	(0.006)	(0.012)	(0.010)	(0.010)	(0.005)
Pandemic*Y_{ijt-1}*Lockdown one	0.048***	0.012	0.007	0.018**	0.018***	0.025*	0.017	0.008	0.005
	(0.010)	(0.011)	(0.012)	(0.008)	(0.007)	(0.014)	(0.011)	(0.011)	(0.006)
Pandemic*Y_{ijt-1}*Lockdown both	0.095***	0.008	0.028**	0.010	0.009	0.042**	0.024*	0.039***	0.004
	(0.013)	(0.017)	(0.014)	(0.013)	(0.009)	(0.017)	(0.013)	(0.014)	(0.009)
N	47804	47804	47804	47804	47804	47804	47804	47804	47804

Source: Nigeria Bureau of Statistics (NBS) and Nigerian Centre for Disease Control (NCDC).
Note: Standard errors, clustered at market pair level, are given in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

In addition to quantifying the impact of lockdown measures, we examine the implication of the spread of the pandemic, measured by the number of COVID-19 cases recorded per population (percent) in each state. As shown in equation (4), these measures of exposure to the pandemic are interacted with the time dummy and lagged price differential to identify whether the speed of adjustment varies across states with varying exposure to the pandemic.

These results (Table 6) show that the spread of the pandemic had a dampening effect on the speed of price adjustment for several food items (local rice, brown bean, and white bean). This suggests that the severity of the pandemic and associated safety concerns likely curtailed trade across formal and informal food markets, creating significant price dispersion across markets. The estimated size of the effects of the severity of the pandemic and, hence additional slowdown in price transmission across markets, is reasonably large. In another robustness exercise, we estimated the implication of the spread of the pandemic by defining an indicator variable for states with high COVID-19 cases (an indicator variable assuming a value of 1 for those states within the last tercile of COVID-19 cases and 0 for other states). The results are reported in Table A2 in the Appendix and provide similar insights.

Slight differences are apparent between the impacts of lockdown measures and COVID-19 cases. While the impacts of lockdown measures, and thus mobility restrictions, appear more pronounced in value chains of foods that are more frequently traded, the impact of the severity of the pandemic (number of COVID-19 cases) also extends to locally traded food items. This is intuitive because lockdown measures are likely to disrupt markets for widely traded foods, while the spread of the pandemic and associated safety concerns may even limit local trade. This varying impact may also be driven by the different reference periods for the lockdown measures and the recorded number of COVID-19 cases. While the lockdown measures were short-lived, the COVID-19 cases data are cumulative counts from March 2020 through October 2021.

Table 6: Effect of the spread of the pandemic on spatial market integration.

	Rice		Wheat	Beans		*Garri*		Fish	
	Imported	Local	Wheat	Brown	White	Yellow	White	Mudfish	Catfish
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Y_{ijt-1}	-0.382***	-0.413***	-0.310***	-0.420***	-0.334***	-0.280***	-0.260***	-0.289***	-0.156***
	(0.007)	(0.007)	(0.005)	(0.010)	(0.005)	(0.005)	(0.006)	(0.005)	(0.004)
Pandemic	0.005***	-0.005***	0.003***	-0.004*	0.006***	-0.012***	-0.005**	0.007***	0.006***
	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)	(0.003)	(0.002)	(0.002)	(0.001)
Pandemic*Y_{ijt-1}	0.206***	0.105***	0.188***	0.229***	0.156***	0.157***	0.144***	0.208***	0.138***
	(0.008)	(0.007)	(0.007)	(0.009)	(0.005)	(0.008)	(0.008)	(0.007)	(0.005)
Pandemic*Y_{ijt-1}*Covid-19 cases	-0.001	0.001	-0.002	0.005***	0.002**	-0.003**	-0.002*	-0.000	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
N	47804	47804	47804	47804	47804	47804	47804	47804	47804

Source: Nigeria Bureau of Statistics (NBS) and Nigerian Centre for Disease Control (NCDC).
Note: Standard errors, clustered at market pair level, are given in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5.4. Heterogeneities and mechanisms in the speed of adjustment

The results described above show that the pandemic and associated lockdown measures weakened spatial market integration. This section provides some heterogeneities that can help explain the extent to which prices achieve equilibrium. The results in Table 7 show the heterogeneous implications of the pandemic across markets with varying distances between them. The coefficients associated with the distance interaction terms suggest that distance between markets increased the dispersion in food prices across states for several commodities (imported rice, white bean, yellow *garri*, and white *garri*). The results suggest that market pairs with greater distances between them experienced larger deterioration in the speed of adjustment during the pandemic. This implies that the impact of the pandemic interacted with underlying attributes of markets, meaning that distant market pairs experienced larger disruptions in market efficiency. This is consistent with recent studies that show remote markets were disproportionally affected by the COVID-19 crisis (Mahajan and Tomar, 2021; Aggarwal et al., 2022; Abay et al., 2021). This is also indicative of the differential impact of the pandemic across households located in urban versus remote areas, as found in several recent studies. Amare et al. (2021a) and Abay et al. (2021) show that households located in remote areas of Nigeria suffered the largest deteriorations in food security. These types of heterogenous impacts imply that reviving the functioning and efficiency of markets may require tailored interventions that specifically target the value chains and market networks that suffered the most.

Table 7: Additional heterogeneities in the speed of adjustment based on distance between markets.

	Rice		Wheat	Beans		*Garri*		Fish	
	Imported	Local	Wheat	Brown	White	Yellow	White	Mudfish	Catfish
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Y_{ijt-1}	-0.383***	-0.413***	-0.310***	-0.417***	-0.333***	-0.280***	-0.259***	-0.289***	-0.155***
	(0.007)	(0.007)	(0.005)	(0.010)	(0.005)	(0.005)	(0.006)	(0.006)	(0.004)
Pandemic	0.005***	-0.005***	0.003***	-0.004**	0.006***	-0.012***	-0.005**	0.007***	0.006***
	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)	(0.003)	(0.002)	(0.002)	(0.001)
Pandemic*Y_{ijt-1}	-0.119	0.188**	0.112	0.218***	0.060	-0.130	0.030	0.388***	0.345***
	(0.090)	(0.078)	(0.092)	(0.067)	(0.060)	(0.087)	(0.074)	(0.101)	(0.070)
Pandemic*Y_{ijt-1}*Distance	0.050***	0.012	0.011	0.004	0.016***	0.043***	0.017*	-0.028	-0.034
	(0.014)	(0.012)	(0.014)	(0.010)	(0.006)	(0.014)	(0.009)	(0.018)	(0.023)
No. observations	47804	47804	47804	47804	47804	47804	47804	47804	47804

Source: Nigeria Bureau of Statistics (NBS) and Nigerian Centre for Disease Control (NCDC).
Note: Standard errors, clustered at market pair level, are given in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 8 shows that the interaction term that includes the pandemic dummy, lagged price differentials, and Internet coverage appears to be negative and statistically significant for most food items analyzed. Thus, the results suggest that access to digital infrastructure may have facilitated spatial market integration for some foods even during the pandemic. This implies that food markets with better access to digital infrastructure were more resilient to disruptions associated with the pandemic. Access to Internet service increased the speed of adjustment for several food items, including imported rice, local rice, wheat, white beans, , catfish, and mudfish. This is consistent with recent evidence showing that markets and services that are functionally dependent on digital infrastructure are likely to be less affected by the pandemic and associated policy responses compared with markets that have a low level of digitalization (Internet access) (Dingel and Neiman, 2020; Abay et al., 2020). Indeed, the pandemic provides insights into the plausible effects of investments that accelerate digitalization, including reducing the vulnerability of food systems to potentially disruptive shocks to food systems. Additional public and private investment in digitalization can transform the functioning and efficiency of markets, especially if it entails digital inclusion of small-scale and informal traders (Aker and Mbiti, 2010; Abay et al., 2020).

Table 8: Heterogeneities in the speed of adjustment based on access to Internet.

	Rice		Wheat	Beans		*Garri*		Fish	
	Imported	Local	Wheat	Brown	White	Yellow	White	Mudfish	Catfish
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Y_{ijt-1}	-0.382***	-0.413***	-0.310***	-0.418***	-0.334***	-0.280***	-0.260***	-0.290***	-0.156***
	(0.007)	(0.007)	(0.005)	(0.010)	(0.005)	(0.005)	(0.006)	(0.005)	(0.004)
Pandemic	0.005***	-0.005***	0.003***	-0.004**	0.006***	-0.012***	-0.005**	0.007***	0.006***
	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)	(0.003)	(0.002)	(0.002)	(0.001)
Pandemic*Y_{ijt-1}	0.207***	0.121***	0.195***	0.235***	0.165***	0.134***	0.130***	0.217***	0.144***
	(0.009)	(0.008)	(0.008)	(0.010)	(0.006)	(0.008)	(0.008)	(0.007)	(0.005)
Pandemic*Y_{ijt-1}*Internet	-0.046	-0.184***	-0.166***	0.115**	-0.042	0.214***	0.110**	-0.153***	-0.174***
	(0.097)	(0.058)	(0.053)	(0.049)	(0.045)	(0.055)	(0.047)	(0.056)	(0.034)
No. observations	47804	47804	47804	47804	47804	47804	47804	47804	47804

Source: Nigeria Bureau of Statistics (NBS); Nigerian Centre for Disease Control (NCDC); and Global System for Mobile Communications Association (GSMA).

Note: Standard errors, clustered at market/state pair level, are given in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

6. CONCLUSIONS

This paper analyzed the impact of the COVID-19 pandemic on domestic spatial food market integration in Nigeria. The analysis used a comprehensive monthly food market price dataset along within a dyadic panel regression framework to evaluate spatial market integration across a diverse set of food items. The estimated econometric models and specifications facilitated evaluation of the impact of the COVID-19 pandemic and associated policy responses on spatial market integration across all 37 states in Nigeria.

We found several important and stylized patterns that can inform post-COVID-19 recovery and investment plans, especially those related to improving and revitalizing the functioning of markets. First, despite some variations across food items and value chains, there is evidence of spatial market integration, and thus, adjustment to long-run equilibrium for all the foods analyzed. However, marked differences arise in estimates across food items. These differences are plausibly explained by differences in the structure of value chains and the role of trade in these value chains. Second, our results reveal that spatial market integration weakened substantially during the pandemic, but such changes in the speed of adjustment and spatial market integration across time varied across value chains. For example, the differences for cereals appear to be modest (and sometimes negligible) but were about fivefold greater for perishable food items such as mudfish and catfish. This is consistent with early evidence showing differential impacts of the pandemic across value chains (Hirvonen et al., 2021; Swinnen and Vos, 2021; Mogues, 2020).

Third, our results show that states that implemented lockdown measures experienced significantly more slowdown in the speed of adjustment, and hence spatial market integration, than those that did not. These impacts increased when both states (in market pairs) implemented lockdown measures. The severity of the pandemic, as measured by the number of COVID-19 cases per population, also had a dampening effect on the speed of adjustment and the magnitude of spatial market integration. Notably, the severity of the pandemic effects extended to products that are both widely traded and more locally traded, while the lockdown effects pertained mainly to widely traded foods.

Finally, the results show that markets located farther from each other experienced greater deterioration in spatial market integration during the pandemic. This is consistent with recent studies that showed remote markets were disproportionally affected by the COVID-19 crisis (Mahajan and Tomar, 2021; Aggarwal et al., 2022; Abay et al., 2021). However, markets with better access to digital infrastructure remained relatively more resilient to food market disruptions associated with the COVID-19 pandemic. This is also consistent with recent studies showing that services that were functionally dependent on digital infrastructure were likely to be less affected by the pandemic and associated policy responses than were markets with low levels of digitalization (Internet access) (Dingel and Neiman, 2020; Abay et al., 2020).

The increase in costs of consumer commodities observed in conjunction with the COVID-19 pandemic, as well as the unfolding food crisis triggered by the Russian-Ukraine war, are inducing significant inflationary pressures on consumers and food markets. Our findings provide evidence regarding changes in the efficiency of markets during a pandemic, which can inform the types of public and private investment needed to revitalize the functioning of markets and value chains affected by different types of shocks. For example, investments in infrastructure, digitalization, and other technologies related to food value chains (such as cold chain development) can improve the efficiency and resilience of markets to future pandemics and shocks. Such investments are particularly important for geographically large countries like Nigeria, where long distances between markets are common and important gaps exist in infrastructure and digitalization.

We acknowledge some limitations to this study. Our analysis builds on previous market integration literature and models that assume that transaction costs and associated frictions across markets may inhibit spatial market integration (Ravallion, 1986; Barrett and Li, 2002). However, most studies empirically evaluating spatial market integration, including ours, rely on price movements and adjustments to infer about spatial market integration. This is not surprising given that data on transaction and transportation costs and sometimes trade volume are not readily available. Incorporating potential movements in transaction costs and trade volume, particularly in response to shocks such as the pandemic, could have enriched the empirical analysis. Future studies may complement our analysis by explicitly accounting for transaction and transport costs as well as trade volumes.

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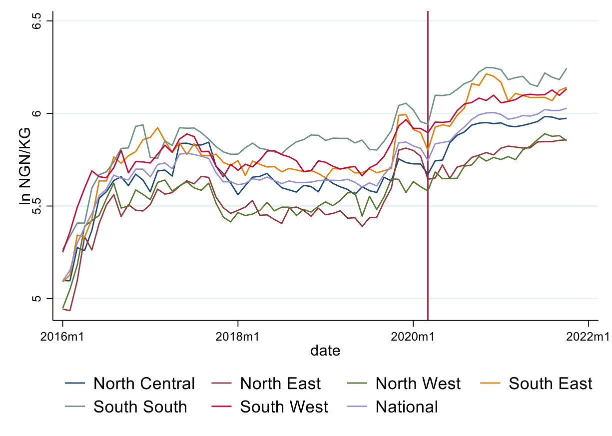
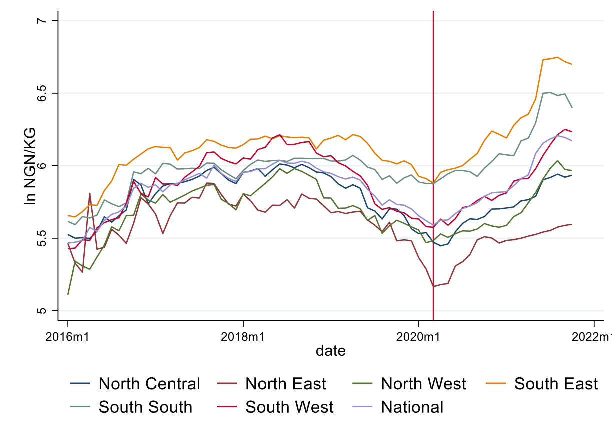
SUPPLEMENTARY MATERIAL FOR ONLINE APPENDIX

Figure A1: Trends in selected food items price data.

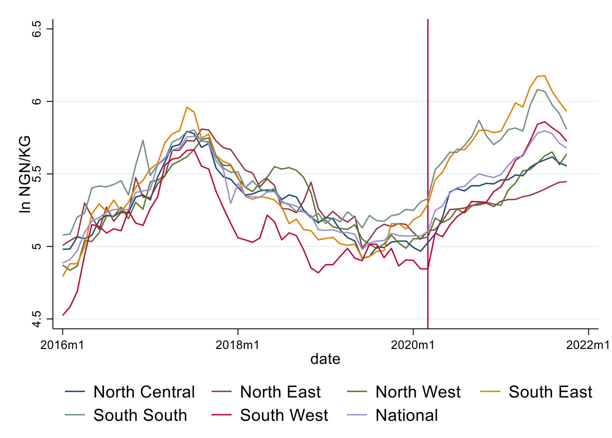
a) Local rice



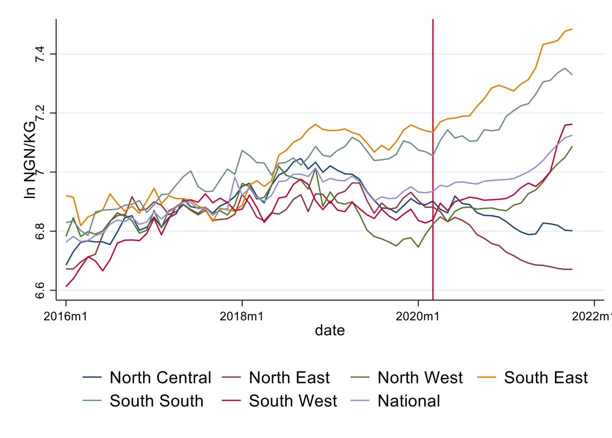
b) Brown bean



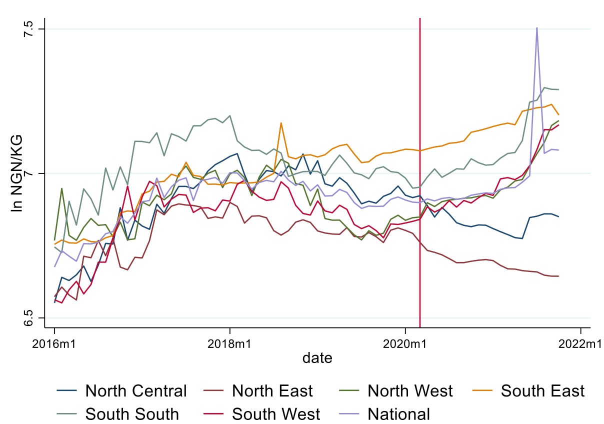
c) White *garri*



d) Catfish

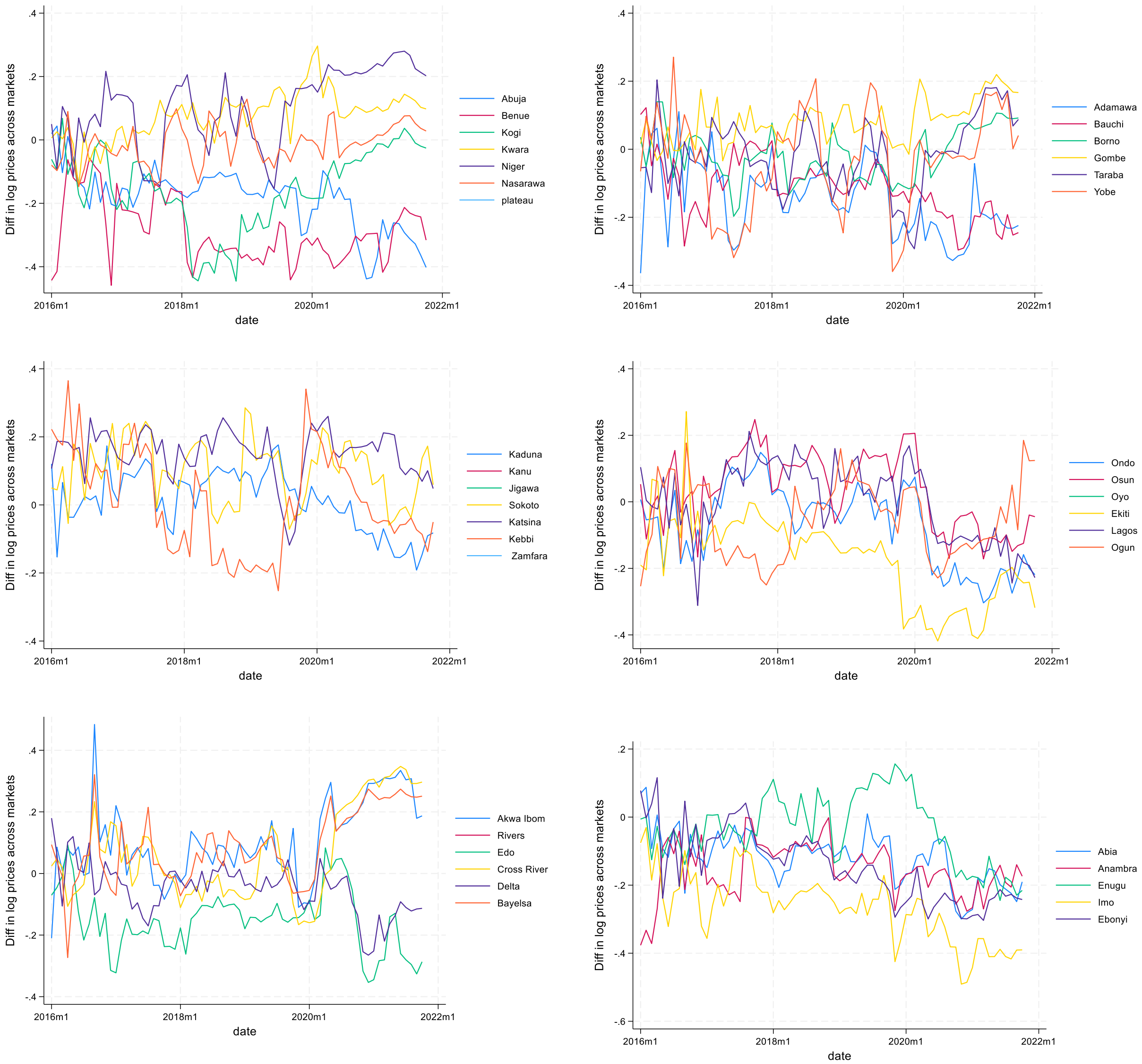


e) Mudfish



Source: Analysis of NBS data over the period 2016:01–2021:10.

Figure A2: Trends in difference in log prices across markets (imported rice).



Source: Analysis of NBS data over the period 2016:01–2021:10.

Figure A3: Trends in difference in log prices across markets (wheat).

Source: Analysis of NBS data over the period 2016:01–2021:10.

Figure A4: Trends in difference in log prices across markets (white *garri*)**.**

Source: Analysis of NBS data over the period 2016:01–2021:10.

Table A1: Half-life coefficients (in months) associated with the speed-of-adjustment parameters before and during the pandemic.

	(1)	(2)	(3)	(4)	5)	(6)
	Pooled	Pre COVID-19	During the pandemic	Pooled	Pre COVID-19	During the pandemic
Panel A:		Local Rice			Imported Rice	
	1.47	1.12	1.46	2.14	1.19	1.85
Panel B:		Wheat				
	2.49	1.71	4.60			
Panel C:		White Bean				Brown Bean
	2.819	1.52	3.84	2.56	1.06	3.43
Panel D:		Yellow *Garri*			Yellow *Garri*	
	2.79	1.70	1.66	3.04	1.85	2.08
Panel E:		Catfish			Mudfish	
	7.26	3.27	14.40	3.09	1.64	5.84

Note: This table reports half-life coefficients estimated via the equation $HC=\frac{\ln(0.5)}{\ln(1-\hat{\alpha})}$ (Goodwin and Piggott, 2001).

Table A2: Effect of spread of the pandemic on spatial market integration.

	Rice		Wheat	Beans		*Garri*		Fish	
	Imported	Local	Wheat	Brown	White	Yellow	White	Mudfish	Catfish
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Y_{ijt-1}	-0.382***	-0.413***	-0.310***	-0.419***	-0.334***	-0.280***	-0.260***	-0.290***	-0.155***
	(0.007)	(0.007)	(0.005)	(0.010)	(0.005)	(0.005)	(0.006)	(0.005)	(0.004)
Pandemic	0.005***	-0.005***	0.003***	-0.004**	0.006***	-0.012***	-0.005**	0.007***	0.006***
	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)	(0.003)	(0.002)	(0.002)	(0.001)
Pandemic*Y_{ijt-1}	0.203***	0.113***	0.161***	0.236***	0.160***	0.156***	0.143***	0.203***	0.132***
	(0.007)	(0.007)	(0.007)	(0.009)	(0.005)	(0.008)	(0.008)	(0.007)	(0.004)
Pandemic*Y_{ijt-1}*High cases	0.002	0.025*	0.025	0.047***	0.017*	0.042	0.029***	0.017**	-0.018**
	(0.014)	(0.015)	(0.017)	(0.012)	(0.009)	(0.025)	(0.011)	(0.008)	(0.009)
N	47804	47804	47804	47804	47804	47804	47804	47804	47804

Source: Nigeria Bureau of Statistics (NBS) and Nigerian Centre for Disease Control (NCDC).
Note: Standard errors, clustered at market pair level, are given in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. We define a dummy variable for states with high COVID-19 cases (an indicator variable assuming a value of 1 for those states within the last tercile of COVID-19 cases and 0 for other states).

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