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Access to Maize Retail Markets and the Impacts of Rural Road Infrastructure in Kenya

Evelyne Nyathira Kihiu and James Njiraini Gachanja

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Abstract

Market access, which is strongly influenced by transport infrastructure, plays a key role in promoting food security through productivity gains, income changes, food prices levels, and changes in dietary diversity and quality. Market access plays a key role in determining food access and food price stability. As such, market access impacts on key developmental priorities, given that food scarcity and the high prices that follow continue to be a source of suffering and poverty in the country and world at large. The realization of the wide differences in development of rural roads, and in turn market access, coupled with differences in food poverty across the country leads to this paper's assessment of the effects of rural transport costs on local maize prices, a key staple food in Kenya. The results highlight the presence of geographical dynamics of market integration, though it is highly concentrated in areas of high agricultural land potential and better road infrastructure. While there is co-movement of prices among some markets, the individual price trends of some markets indicate that indeed some markets are not integrated. Food poverty is also depicted to be more severe in areas with less clustering of food markets. Results from empirical estimations indicate that improved rural road infrastructure is associated with lower maize prices in retail markets. The study also finds presence of spatial dependence in maize prices between one county and neighbouring counties. Spatial dependence shows the propensity for nearby locations or counties to influence each other and possess similar attributes and can be strengthened through transport networks between markets. The findings highlight the instrumental role of strengthening the link between markets, which would promote local market integration and thereby smoothen commodity prices by improving rural road infrastructure to enhance food access and food price stability in Kenya.

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Abbreviations and Acronyms

FEWS NET	Famine Early Warning Systems Network
IFPRI	International Food Policy Research Institute
KIHBS	Kenya Integrated Household Budget Survey
KNBS	Kenya National Bureau of Statistics
LEI	Leading Economic Indicators
RAI	Rural Access Index
SDGs	Sustainable Development Goals
SSA	South of the Sahara
USAID	United States Agency for International Development
WFP	World Food Programme

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1. Introduction

The development agenda recognizes the importance of market access on promoting food and improved nutrition through productivity gains, income changes, food prices levels, and changes in dietary diversity and quality (Timmer, 2017; Von Braun, 2009). Functioning of markets has intersections with all four dimensions of food security: availability, access, utilization, and stability (Gadhok, 2016). On availability, through trade, markets increase the quantity and variety of food available through identification of food deficit and surplus areas. Distribution of natural resources and productivity potential across different agro-ecological zones does not match, and hence the need to achieve balance through markets. This balance is achieved through the crucial role markets play in diversifying food supply and compensating food supply deficits. On access, markets access determines prices and price transmission and producers' participation in inputs and output market networks to sell their farm produce (Gadhok, 2016). Further, market access is a major precondition for farmers to overcome subsistence farming and individual economic situation. In terms of utilization, the functioning of markets is a major precondition for rural and urban population to access nutritious, sufficient, and safe food to enhance food and nutrition security (Brenton and Nyawo, 2019; Stifel and Minten, 2017; Kihiu and Amuakwa-Mensah, 2021). Other than balancing food deficits and surpluses on domestic markets and broaden consumer choices (Mrdalj and El Bilali, 2021), agricultural food markets make populations more resilient to fluctuating boundary conditions induced by human activities and biophysical factors such as climatic factors (Gadhok, 2016). The functioning of markets is thus essential to achieving SDGs 1 and 2, and thus guaranteeing the functionality of market needs to be in concordance with the related SDGs.

Focusing on the link between market access and food access dimension throughout the world, food access and food price stability are key developmental priorities, as food scarcity and the high prices that follow continue to be a source of suffering and poverty (Bondemark, 2020). Food access is determined by both economic and physical access to food (FAO, 2015). While economic access is influenced by food prices, disposable income, and the provision of and access to social support. Physical access is influenced by the availability and quality of infrastructure and supportive installations responsible for the well-functioning of markets. Food prices is a key variable that directly determines a population's economic access to diverse food alleviating populations from hunger and malnutrition. On the other hand, infrastructure development, which affects the development of marketing channels and distribution networks, determines private investments and players entry into markets, all which play a key role in overall physical access and in turn economic access-food affordability (FAO, 2015; Bondemark, 2020). As further highlighted in FAO (2015), remoteness and insufficient infrastructure can make it too costly for sellers to actively participate in marketing channels, thus decreasing their engagement in markets, which ultimately affects the access of commodities at reasonable prices.

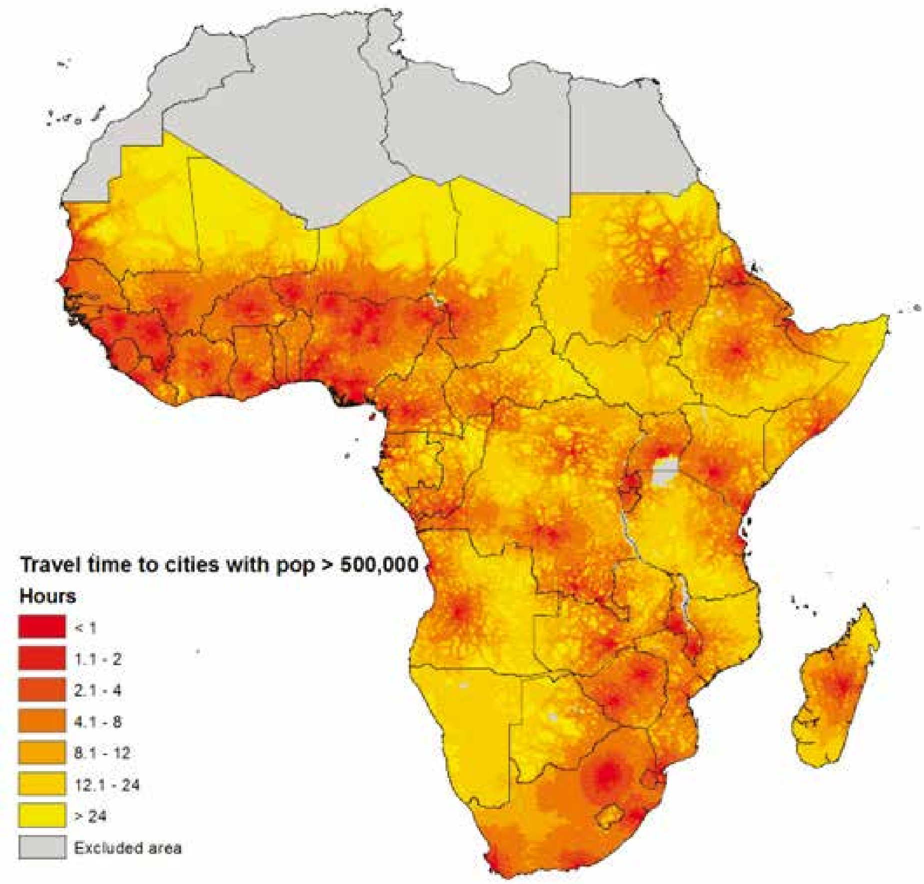
Market access largely depends on marketing margins, which are strongly influenced by the level of marketing and transactional costs (Baltenweck and Staal, 2007). As such, marketing costs, and in turn market access, are closely associated with distance to markets, the nature of infrastructure and the systems operating between demand and supply zones (Baltenweck and Staal, 2007). Costs, distance and travel time have been used as metrics for determining market access, though access can be to institution services such as credit and extension services that improve food security through access and utilization (Ahmed et al., 2017).

Development of domestic transport investments in developed economies has resulted in declined transport costs (Berg et al., 2017; Minten and Kyle, 1999). Though expensive, enhanced local transport infrastructure is central to reduced transport costs, which has been associated with agricultural transformations by increasing trade and creating incentives to farmers to shift to commercial farming; lower food prices and price dispersions; increased supply responses; improved allocative efficiency; increased high-input and technological adoption; access to larger markets; and enhanced economic growth (Zant, 2018; Le Cottya et al., 2017; Casaburi et al., 2013; Minten and Kyle, 1999). The rationale behind the effect of transport investments on food prices is that enhanced local transport infrastructure strengthens the link between markets, and in turn supports and promotes market integration or "the co-movement of prices between different markets" (Shin, 2010), thereby smoothing price volatility (Le Cotty et al., 2017). Conversely, lack of such infrastructure limits price transmission and price integration (Minten and Kyle, 1999). Thus, reduced transport cost matters because it improves access to markets and food prices.

1.1 Problem Statement

In Kenya and Africa at large, market access varies largely across space, and one of the major reasons attributed to this are transport costs (Figure 1). High transport costs in the African region stem from distance to markets and lack of quality infrastructure, proxied by road quality, which reduce market access (Baltenweck and Staal, 2007; Shin, 2010; Le Cotty et al., 2017).

Figure 1: Travel time to markets in Africa south of the Sahara: Market access



Source: HarvestChoice; International Food Policy Research Institute (IFPRI), 2016, Travel Time to Markets in Africa South of the Sahara, https://doi.org/10.7910/DVN/YKDWJD, Harvard Dataverse, V2

Poor transport infrastructure can have significant implications on food security. Poor infrastructure can make it too costly for farmers to participate in marketing channels, thereby limiting the surplus they are willing to sell. Transport infrastructure conditions may thus prevent participants of market networks from moving commodities from one locality to another. Further, transport infrastructure affects how integrated domestic markets are, which is likely to magnify price volatility arising from agri-food shocks and stressors. Transport plays a key role in enhancing market integration, a key determinant for food security. For food security and poverty-reducing initiatives to be sustainable over time, Timmer (2017) and Shively and Thapa (2017) highlight the indispensable need of integrating markets. Highly fragmented agri-food markets are potential determinants of food security and food price volatility by allowing domestic trade to buffer supply shocks within the country. Shively and Thapa (2017) note that when local markets are isolated and are characterized by insufficient production, food price instability and incomplete price transmissions are likely to occur. In developed countries, full integration of markets has almost been achieved but in developing countries, market integration remains a challenge particularly in the rural areas (Timmer, 2017).

Coupled with differences in food poverty across counties (KNBS, 2018), the realization of wide differences in market access (Figure 1) in Kenya leads to this paper's assessment of the effects of transport costs on local retail maize prices, a key staple food in the country. In this paper, the study contributes to the existing literature (Okoye et al., 2016; Zant, 2018; Shively and Thapa, 2017; Schmitt and Kramer, 2009; Le Cotty et. al., 2017; Bwalya et al., 2013) by providing evidence on the impact of transport costs on food market prices in Kenya. The study is aware that these studies did not carry out a geospatial analysis of market integration. The value of understanding the co-movement of prices between different markets-market integration through a geographic perspective is that it can provide insights to threats to food security (Shin, 2010). Thus, the second contribution involves measuring local or neighbourhood levels of market integration. This involves using a local indicator of spatial association to calculate the correlation of maize prices between a retail market and its nearest neighbours.

Given transport infrastructure represents a large share of government expenditure, it is important that use of resources relies on a detailed understanding of how transport policies can affect food prices. The assessment will have immediate policy relevance in promoting food security particularly in mitigating the effects of local supply or demand shocks on retail maize prices and food prices in general.

1.2 Objectives

The paper assesses whether differences in road transport infrastructure, and in turn transport costs, across counties are a source of maize retail price differences and whether these differences modify price transmission between domestic maize retail markets. The specific objectives of the study are:

(i) Analyse the spatial patterns between key maize retail markets, food poverty and road infrastructure at the county level.

(ii) Examine the role of transport cost on maize food prices from the key maize retail markets.

(iii) Evaluate local or neighbourhood levels of market integration.

The study hypothesizes that whenever the price of a food commodity in a market exceeds the price of the same commodity in a different market by more than the transportation costs, then producers engage in spatial arbitrage until prices converge. Thus, enhancing transport infrastructure within counties would strengthen the link between markets, thereby smoothing commodity prices. The paper further hypothesizes that market integration is localized, with transport costs altering price transmissions between markets.

1.3 Outline of the Paper

The rest of the paper is organized as follows: In Section 2, the study presents an overview of empirical and theoretical literature. The theoretical framework is also outlined in this section. Section 3 outlines the conceptualization of the study and describes the data and empirical strategy used in the analysis. Section 4 presents and discusses the regression results. The last section presents the conclusions and discusses the policy implications from the study.

2. Literature Review and Theoretical Framework

2.1 Theoretical Literature

General literature on transport development observes that improving the transport network reduces transport costs, which leads to increase in market access (Berg et al., 2017). In Sub-Saharan African, poor transport development and market access is mainly characterized by remoteness, lack of quality infrastructure, poor infrastructure network, travel time and non-physical costs (legal, information, screening partners, bargaining, and monitoring costs).

The location theory by Von Thünen (1826) is one of the earliest expressions of the relationship between transport costs and market prices in a spatial pattern (Chamberlin and Jayne, 2013). Von Thünen (1826) insights were that market prices, relative to production costs, implicitly define locational rent. Given production costs were taken to remain constant and transportation costs goods between locations of production and exchange are directly related to distance, from the theory, transportation costs and locational rent are inversely related as transport costs eat into the locational rent. Thus, the market price decays with physical distance. The theory therefore suggests that market activity in rural areas is greatly influenced by physical market access.

The transaction costs theory has been applied in food input and output markets to explain market participant behaviour (Bwalya et al., 2013). Transaction costs can be defined as costs incurred by buyers that are not transferred to sellers or costs payable by sellers but are not transferred to the buyers (Kissel, 2006), leading to a rise in buying prices as selling prices decline, and resulting to a price band that is unprofitable for sellers and buyers (Key et al., 2000). The latter study classifies transaction costs into variable/proportional transaction costs originating from transportation and asymmetric information costs. Time invariant/fixed costs include search costs for a buyer, bargaining costs due to imperfections in market price information, screening for reliable buyers where farmers sell on credit, enforcement costs for defaulting partners and supervision costs spent on farm labour. High transaction costs make markets unavailable, forcing households to be self-sufficient as they are faced with wide margins between low selling price and high buying price. This leads to large subsistence farming. According to de Janvry et al (1991), while the width of the price band is determined by market infrastructure, mark-ups by merchants, search costs, recruitment and supervision costs, risk associated with uncertain prices and availabilities, and other transactions costs, the poorer the infrastructure, the less competitive the marketing systems, the less information is available, and the more risky the transactions. This further increases the size of this band (de Janvry et al., 1991).

Therefore, the price margins between high buying price and low selling price widen the poorer the infrastructure.

The Samuelson (1952) spatial price equilibrium model has been used to study problems in agricultural markets (Le Cotty et al., 2017). The theorem recognizes the importance of space and transportation costs associated with movement of commodities from a supply market to a demand market that are spatially separated. For trade to occur between a supply and demand market pair, at equilibrium, the supply price at supply market plus the transaction cost between the pair of markets must be equal to the demand price at demand market. However, if the supply price plus the transaction cost exceeds the demand price, then there will be no movement of goods between the supply and demand market pair.

2.2 Empirical Literature

Infrastructure improvements have been associated with improved market access and lower food prices. Transport investments often result to agricultural transformation by promoting trade networks and linkages. Transport investments also have the potential of promoting food and nutrition security as transport costs are correlated with food prices (Berg et al., 2015). Further, by lowering transport costs, transport investments are capable of building resilience of communities by making local food prices less responsive to productivity shocks.

In Nepal, Shively and Thapa (2017) studied the market-transport infrastructure-food prices nexus. There was a significant relationship between improved market access, proxied by a road density index and a reduction in the mean and variance of wheat and rice prices. In addition, there were weak price transmissions between regional and local markets, though prices were persistent between periods at local levels. Fuel prices were associated with higher food prices, although the holistic impact on the overall food prices was moderate. Thus, road and bridges have a significant effect of price and price volatility in local and regional food markets in Nepal.

In assessment of the role of market access in enhancing food security in rural Pakistan, Ahmed et al. (2017) found that a unit increase in paved road increased the probability of a household being food secure by 2 per cent, implying that good roads reduce production costs , which increases farm incomes, thereby affecting food security indirectly. An increase in transport cost, a different indicator of market access used, led to a decrease in food security status, indicating that transport costs lowered sales margins and in turn farm incomes and spending on food consumption.

In Africa, Casaburi et al. (2013) observed that improved rural roads reduced cassava and rice prices, the two most important staple crops in Sierra Leone especially in remote and least productive areas far away from urban centres. In addition, the price reductions were more pronounced for cassava, given it was bulkier and more expensive to transport than unprocessed rice. The results provided evidence of food price reductions in response to road transport improvements and can be interpreted that improvements in transport infrastructure facilitated market access by reducing transport costs on rural roads. In their analysis of the role of market remoteness on maize price volatility in Burkina Faso, Le Cotty et al. (2017) show that transport costs increased volatility in rural markets when volatility emanates from local factors. The results suggest that enhanced transport infrastructure is likely to strengthen local market integration, thereby reducing price volatility. Similarly, in Malawi, Zant (2018) in a study assessing the impact of low-cost transport on agricultural commodity prices across markets, the author observed that low transportation costs explained 14 to 17 per cent reduction in price dispersion across markets. The observations implied that low transport costs enhance arbitrage opportunities, resulting to lower price dispersion across markets.

Investigating the effect of distance and road quality on prices in Congo, formerly Zaire, Minten and Kyle (1999) found that food price differentials in producer zones and Kinshasa were due to transport costs. A kilometre travelled on poor roads reduced producer prices four times compared to travelling on proper road. These transport costs were transmitted to prices earned by producers, hence reducing the size of the food markets and food varieties. Similarly, in Madagascar, Minten and Kyle (1999) asserts that regions with poor infrastructure had lower producer prices during harvest periods, with presence of roads showing up relatively higher producer prices. While price levels were shown to decrease significantly with increased distances to main roads and decreased quality of infrastructure, road distance was shown to matter more than road quality given the lack of a strong relationship between road quality and producer prices. Further, while transportation costs are transmitted to producer prices, good infrastructure had no impact on trader competition, highlighting the complimentary role of soft infrastructure in reducing price volatility, enhancing producer prices and market integration.

On hard infrastructure being an important determinant of food and nutritional security, in Ethiopia, Brenton and Nyawo (2019) assessed the impact of market access and food prices on child nutrition rates. Adapting panel data and fixed effects, the study shows that an increase in maize, teff and wheat prices and proximity to main roads improved nutrition and health for children aged 6-59 months. These results corroborate Headey (2016) that poverty reduction is closely linked to rising crop prices in many developing countries. Further, Arndt et al (2016) in Mozambique used quarterly food price inflation and household survey data to study the link between inflation rates and child nutrition status. From their propensity score matching approach, stunting and wasting rates declined when food price inflation was low. Previously, Stifel and Minten (2017) accessed the link between market access, nutrition and well-being in Ethiopia using various well-being indicators: food security, education, consumption, diverse diet portions and mother and child nutrition. The findings show that access to markets by households, as estimated by transaction costs to the closest market, has a direct relationship with consumption rates and food security through the marketing and agricultural production nexus. Improving feeder roads would lower transaction costs that increase household incomes enhancing consumption patterns, dietary diversity and health. Hirvonen et al (2017) run an instrumental variable model on Ethiopian survey data with details on caregiver's knowledge on nutrition and feeding, pre-school children's diets and market access data proxied by alternative transport costs to control for endogeneity problems. The results show that nutrition awareness improves diet variations in children only in regions with good market access, and thus calling for complementary impacts of good market access in expanding nutrition knowledge.

In Kenya, Baltenweck and Staal (2007) assessed the impact of market access on milk and bean farmgate prices in smallscale holder farms in Kenyan highlands. The study employed both simple measures (distance by road type) and composite measures (weighted distance, negative exponential and gravity models) of market access and applied to spatial price formation approaches household-specific transaction cost. The simplified market access indicator showed that increased distances (lower market access) increased the input prices and lowered the output prices. On distance by road type, marketing costs were shown to increase by poorer road quality. Findings from composite indicators were either counter-intuitive or non-significant. Their interpretation was found to be difficult as the measures have no units. Simple market access measures were observed to be easier to interpret with straightforward policy implications. Spatial price formation using simple road distances were able to capture both observed and unobserved transactions costs, and thus provide potentially more accurate measures of marketing costs as opposed to using fixed and variable costs reported by market agents. Marketing agents are likely to be oblivious of some unobserved transaction costs. However, a study by Kamara (2004) on the impact of market access to farm productivity and input use prefers a travel time proxy compared to distance due to wealth and farm resources that would determine the mode of transport in Machakos District, Kenya. The three stage least square regression analysis showed that productivity increased with market access through the distribution of incomes was dependent on economies of scale other diversified market access options among farmers.

3. Methods

3.1 Theoretical Framework

To model transport cost and price volatility, the paper applies the Samuelson (1952) transport cost model as presented by Le Cotty et al. (2017). Under the framework, price differences between two markets equal the cost of transporting the commodity from the low-price market to the high price market (Le Cotty et al., 2017). This paper applies the framework in analysing the relationship between commodity food prices and market transport costs. The innovations made to the existing framework include consideration of the markets at the county level, consideration of both distance and quality/nature of road in the assessment of transport costs by use of the Rural Access Index, and extension of the analysis to include spatial aspects to measure the level of market integration.

To do this, let P_a and P_b be the market prices at the main markets in areas *A* and *B*, respectively. Let the main market at *A* be the high-price market and the main market at *B* be the low-price market and *T* be the transport cost between the two main markets. Letting the quantity exchanged from low-price market to the high price market be given by E to have:

$$P_a \geq P_b + T \text{ if } E > 0$$

$$P_a < P_b + T \text{ if } E = 0 \quad (1)$$

where $E>0$ means quantity exchanged from the low-price market *B* to the high price market *A* is greater than 0 (there is trade), $E=0$ means there is no quantity exchanged (no trade) from market *B* to market *A* due to the high price in market *B*, and transport costs are taken to directly increase with poor road quality.

Other than transport costs, there are additional transaction costs, which all together form total transactional costs. These include additional variable transaction cost and fixed transaction costs (Le Cotty et al., 2017). Recognition of these additional transaction costs leads to equation 2 below:

$$P_a \geq P_b + T + V(T) + F \text{ if } E > 0$$

$$P_a < P_b + T + V(T) + F \text{ if } E = 0) \quad (2)$$

where $V(T)$ is the sum of variable transaction costs, which increase with poor connectivity/poor road quality such as costs linked to the collection of information on prices, and *F* is the sum of fixed transaction costs, which do not depend on connectivity/road quality and are the same for all markets, such as administrative costs related to trade controls (Le Cotty et al., 2017). The intuition from equations 1 and 2 is that high transport costs, proxied by road quality, impacts transmission of price level between markets, and amplifies price volatility and high price levels in the remote markets.

Following Samuelson (1952) and Le Cotty et al. (2017) trade models, excess supply is defined as the difference between local supply and local demand in the low-price market (i.e., the selling area). Excess demand is defined as the difference between demand in the buying area (i.e., high-price market) and all other sources of supply. The other sources of supply include low-price markets in other areas/ markets other than the one being analysed. Excess supply, x_t, is a monthly excess supply where subscript t is a monthly index. x_t is a function of the local price P_t^b prevailing in the low-price market at month t, the stock volume S_t available at month t. The time of the year t as decisions to sell are informed by the time to go until next harvest, and a monthly shock on commodity (maize) availability θ_t due to unexpected events affecting local supply or local demand.

$$x_t(P_t^b,S_t,t,\theta_t) \qquad (3)$$

With the assumption that there is no carryover, stock volume is given by the latest yearly harvest H minus the sum of what has been supplied since the latest harvest:

$$S_t=H-\sum_{i=0}^{t}x_i \qquad (4)$$

From equations (3) and (4) and subsequent iterations of the stock volume, $S_t (H,P^o_b,P^1_b,\ldots,P^t_b,t,\theta_o,\ldots,\theta_t)$ is obtained, and thus the excess supply equation can be expressed as follows:

$$x_t(H,P^o_b,P^1_b,\ldots,P^t_b,t,\theta_o,\theta_1,\ldots,\theta_t) \qquad (5)$$

The monthly excess demand from the high-price market is expressed as follows, assuming all other determinants other than price are given:

$$m_t(P_t^a) \qquad (6)$$

The monthly demand is taken to be constant during the year and is decreasing and convex in price: $m_t'<0$, $m_t''>0$. The two market clearing conditions given by:

$$T=P^t_a-P^t_b-V(T)-F;x_t\,(H,P^o_b,P^1_b,\ldots,P^t_b,t,\theta_o,\theta_1,\ldots,\theta_t)=m_t\,(P_t^b+T+V(T)+F) \qquad (7)$$

$$T>P_t^a-P_t^b-V(T)-F;\ x_t=0 \qquad (8)$$

If $T>P_t^a-P_t^b-V(T)-F;\ x_t=0$, then exchange does not take place, hence no price transmissions between the two markets and thus the prices are independent. However, if

$T=P_t^a-P_t^b-V(T)-F$, exchange does occur and the equilibrium defines a market price that depends on all exogenous variables, $P_t(b^*)\ (H,P_o^b,P_1^b,\ldots,P^b_{t-1},t,\theta_o,\ldots,\theta_t,T,F)$. This leads to two price regimes as shown in equations (9) and (10):

$$T=P_t^a-P_t^b-V(T)-F;\ P_t^b=P^{b*}_t\,(H,P_o^b,P_1^b,\ldots,P^b_{t-1},\ t,\ \theta_o,\ldots,\theta_t,T,F) \qquad (9)$$

$$T>P_t^a-P_t^b-V(T)-F;\ P_t^b=P_t^b\ (H,P_o^b,P_1^b,\dots,P^b_{t-1}b,t,\theta_o,\dots,\theta_t) \qquad (10)$$

Where markets are connected leading to exchange of commodities, price volatility is the same. However, where markets are disconnected, the volatility in prices is different. Further, in disconnected markets, unexpected prices shocks, θ_t, have a greater impact on prices in a disconnected market compared to that in a disconnected market. This is illustrated using equations 7 (connected market) and (8) disconnected market). Totally differentiating equations (7) and (8) leads to equations (11) and (12) respectively:

$$\partial P_t^b = -\frac{\frac{\partial x_t}{\partial H}}{\frac{\partial x_t}{\partial P_t}-m_t'}\partial H - \frac{\frac{\partial x_t}{\partial \theta_t}}{\frac{\partial x_t}{\partial P_t}-m_t'}\partial \theta_t + \frac{m_t'(1+V')}{\frac{\partial x_t}{\partial P_t}-m_t'}\partial T + \frac{m_t'}{\frac{\partial x_t}{\partial P_t}-m_t'}\partial F - \frac{\frac{\partial x_t}{\partial t}}{\frac{\partial x_t}{\partial P_t}-m_t'}\partial t - \sum_{i=0}^{t-1}\frac{\frac{\partial x_t}{\partial P_i^b}}{\frac{\partial x_t}{\partial P_t}-m_t'}\partial P_i^b - \sum_{i=0}^{t-1}\frac{\frac{\partial x_t}{\partial \theta_i^b}}{\frac{\partial x_t}{\partial P_t}-m_t'}\partial \theta_i^b \qquad (11)$$

$$\partial P_t^b = -\frac{\frac{\partial x_t}{\partial H}}{\frac{\partial x_t}{\partial P_t}}\partial H - \frac{\frac{\partial x_t}{\partial \theta_t}}{\frac{\partial x_t}{\partial P_t}}\partial \theta_t - \frac{\frac{\partial x_t}{\partial t}}{\frac{\partial x_t}{\partial P_t}}\partial t - \sum_{i=0}^{t-1}\frac{\frac{\partial x_t}{\partial P_t^b}}{\frac{\partial x_t}{\partial P_t}}\partial P_t^b - \sum_{i=0}^{t-1}\frac{\frac{\partial x_t}{\partial \theta_t^b}}{\frac{\partial x_t}{\partial P_t}}\partial \theta_t^b \qquad (12)$$

The second term in equations (11) and (12) show the effect of a positive shock on excess supply $\partial x_t/\partial\theta_t$ on price. The equations show that unexpected events (shocks) have a greater effect on prices in disconnected markets. This is shown by the size of the denominator of the second term in the two equations. Since the probability of markets being disconnected increases with transport costs, T, the above shows that the effects of unexpected shocks on food prices, and in turn food price volatility is greater with T. This highlights the influence transport infrastructure has on food prices through its effect on market integration.

3.2 Empirical Estimation

The typical model structure to describe the relationship between rural road infrastructure on maize market prices is guided by equation 12 above. From equation 12, market prices are influenced by their lagged values, harvest, unexpected shocks, transport costs, excess supply and demand. For simplicity but without loss of rigor and guided by similar studies (Le Cotty et al., 2017; Shively and Thapa, 2017) unexpected shocks are captured in the residuals, while excess demand, excess supply and harvest are proxied by population density, agro-ecological zones, and time of the year to capture harvest and lean periods.

Adding additional controls, the model used is described as:

$$P_{it}=\beta_o+\beta_1P_{it-1}+\beta_2RAI_i+\sum_n\beta_{3n}X_{n,it}+\beta_4time_t+\beta_5Agroecological\text{-}zone+\beta_6\omega+\beta_7\emptyset+\beta_8\,\mu+\varepsilon_{it} \qquad (13)$$

Where P_{it} represents the average retail price for dry maize in key markets at county *i* at month *t*; *AI* is a variable that measures the proportion of the rural population who live within 2 km of an all-season road in county *i* as earlier explained; $X_{n,it}$ is a vector of *n* variables at time *t* determining maize market prices across markets in county *i*; time *t* is a time trend; *Agroecological_zone, ω, Ø,* and *μ* are agro-ecological zones, county, month and year fixed effects; and ε_{it} is a cluster robust error term. As illustrated in Zant (2018) and Aggarwal et al. (2018), the monthly and yearly fixed effects help to control for country-wide variations in production and demand over the months and years, such as variations in rain seasons and drought years.

3.3 Data and Variables

To carry out the empirical estimation, our analysis relies on monthly market prices of dry maize from key maize retail markets as observed from various issues of the Leading Economic Indicators (LEI), reported by the Kenya National Bureau of Statistics (KNBS). The average monthly retail prices for dry maize, a major Kenyan food staple, is employed to serve as an indication of fluctuations in food prices. Similar indicators are adopted in studies by Grace et al. (2014), Aggarwal et al. (2018), and Le Cotty et al. (2017). While the study has these data from 2007 for around 130 main markets in various counties, we use a limited subset of average prices main markets at the county level (47 counties) for the period from January 2014 to December 2020 for the purpose of this study. Use of price data at the county level is guided by the level at which other key variables, mainly the transport cost data, is available. In addition, not all markets have complete price data over the years but at the county level, the issue of completeness of the data substantially drops.

From literature, the concept of market transport costs combines several elements, including distance to a market destination, time to a market destination and the quality of the route or impedance level in terms of relative ease of movement (Baltenweck and Staal, 2007; Le Cotty et al., 2017; Zant, 2018; Berg et al., 2017; Aggarwal et al., 2018). Based on this, market transport costs in this study are proxied by Rural Access Index (RAI). RAI measures "the number of rural people who live within two kilometres (typically equivalent to a walk of 20-25 minutes) of an all-season road as a proportion of the total rural population" (Roberts et al., 2006). RAI captures the key elements associated with market transport cost. It is also considered as a key development indicator in enhancing access to markets (Roberts et al., 2006).

Additional variables include agro-ecological zones fixed effects (Shively andThapa, 2017), population density (Bondemark, 2020; Le Cotty et al., 2017; Shively andThapa, 2017) and the exchange rate (Shively and Thapa, 2017; Le Cotty et al., 2017; Webb, 2010). It is expected that agro-ecological zones associated with more favourable agro-climatic conditions are associated with higher productivity, and in turn availability of the maize food commodity increases supply, which reduces average prices of commodities (Shively and Thapa, 2017). The agro-ecological zones are classified as per the Agricultural Sector Transformation and Growth Strategy (ASTGS) 2019 - 2029. Population density, which accounts for demand shifts, is measured as number of persons per square kilometre in a county. The data is obtained from the 2019 Kenya Population and Housing Census.

The strong and important link between exchange rates and food prices has been established in several empirical studies (Abbott et al., 2008; Ikuemonisan, et al., 2018; Sansone and Justel, 2016). The studies show that food prices are not only affected by supply-demand events in individual commodity markets but also by macroeconomic forces that establish the environment within which markets adapt. Exchange rate is a key macroeconomic variable that determines how global prices affect domestic prices. The exchange rate, which is expected to influence both demand and supply, is obtained from various issues of the Leading Economic Indicators published by the Kenya National Bureau of Statistics (KNBS).

Variables used in the spatial mappings include the livelihood zones shapefile. The livelihood zone shapefile is obtained from Famine Early Warning Systems Network (FEWS NET) website, jointly prepared by USAID, WFP, Government of Kenya, and FEWS NET. The livelihood zones show areas within which people share a similar pattern of livelihood; that is, identical options for obtaining food, income and market opportunities.

Geographically disaggregated layers of maize markets are generated using maize market locations from the various Leading Economic Indicators (2015-2020) as reported by the Kenya National Bureau of Statistics (KNBS). In addition, the food poverty layer is developed using the food poverty severity index derived by the Kenya National Bureau of Statistics based on the 2015/16 Kenya Integrated Household Budget Survey (KIHBS). A high food poverty severity index indicates that food poverty is more severe in a specified county.

On transport, geographically disaggregated layers of the Rural Access Index (RAI) are developed using the 2019 RAI data from the Kenya Roads Board (KRB). In addition to RAI, the KRB geodatabase is used to map the road network within counties. The geodatabase is based on the KRB road inventory and condition survey carried out between 2007 and 2009 (KRB, 2017). Table 1 provides a summary of the variables used in the study.

Table 1: Descriptive statistics

Variable	Description	Mean	Std. Dev.	Min	Max	Data Source
ln_ Market Prices	Natural logarithm of average monthly retail prices for dry maize (per Kg), 2014-2020 in key markets across counties	3.636	0.255	2.749	4.605	Leading Economic Indicators as reported by KNBS
RAI	County Rural Access Index (RAI) 2018. The Rural Access Index (RAI) measures the proportion of the rural population who live within 2km of an all-season road	71.267	29.073	11	100	2019 RAI data from the Kenya Roads Board
ln_ Population Density	Natural logarithm of county population density where population density is calculated as the number of persons per square kilometre	5.126	1.573	1.792	8.740	2019 Kenya Population and Housing Census.
ln_ USDKES	Natural logarithm of USD to KES Exchange Rate	4.606	0.064	4.457	4.753	KNBS
Agro-ecological zone 1	Share of counties in the North and Central ASALs agro-ecological zone: Rainfall 400-800mm	0.178	0.382	0	1	Classified as per the ASTGS 2019 - 2029
Agro-ecological zone 2	Share of counties in the Rift Valley, Semi-Arid Uplands and Coast agro-ecological zone: - Rainfall 600-1,200mm	0.289	0.453	0	1	Classified as per the ASTGS 2019 - 2029
Agro-ecological zone 3	Share of counties in the Central Highlands and Western agro-ecological zone: - Rainfall 1,200-2,000mm	0.533	0.499	0	1	Classified as per the ASTGS 2019 - 2029
Spatial Data						
KLZ	Kenya's Livelihood Zone Shapefile					FEWS NET
Markets	Market Locations Layer					Generated using market locations from the various issues of LEI by KNBS
Food Poverty	Food Poverty Layer					Generated using food poverty severity index from the 2015/16 KIHBS

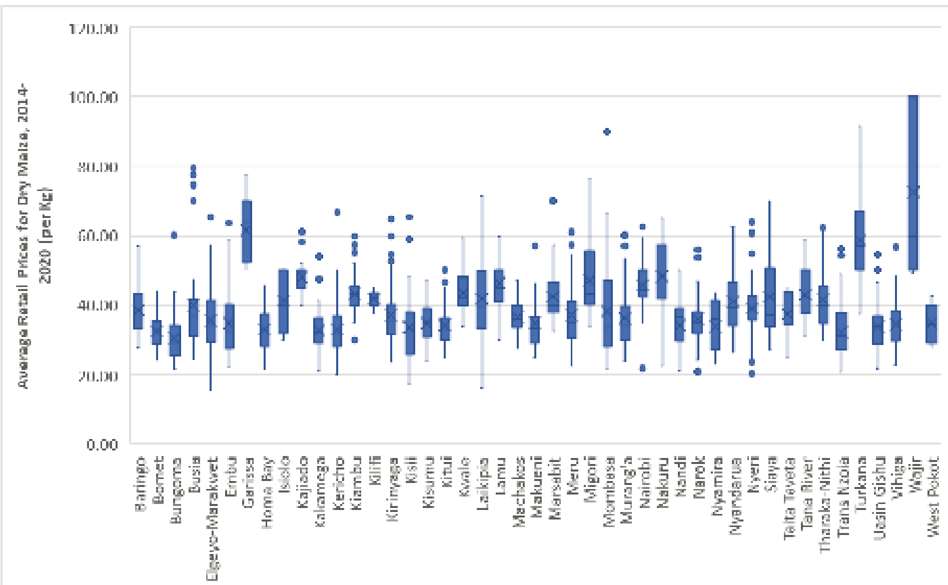
RAI	RAI Layer					Generated using 2019 RAI data from the Kenya Roads Board
Road Network	Road network					KRB geodatabase

3.4 Evolution of Maize Prices in Markets Across and Spatial Mappings

Figure 2 charts the development of average retail prices for dry maize in key markets across counties in Kenya from January 2014 to December 2020 as a series of box-and-whisker plots. The box and whisker chart shows the distribution of maize prices data into quartiles, highlighting the mean and outliers.

The inter-quartile range of the data is portrayed as a vertical box and bisected mean markers. The whiskers represent the upper- and lower-extremities of the data and points outside the whiskers are considered as outliers. The variability of maize prices in counties can be ascertained from the plots.

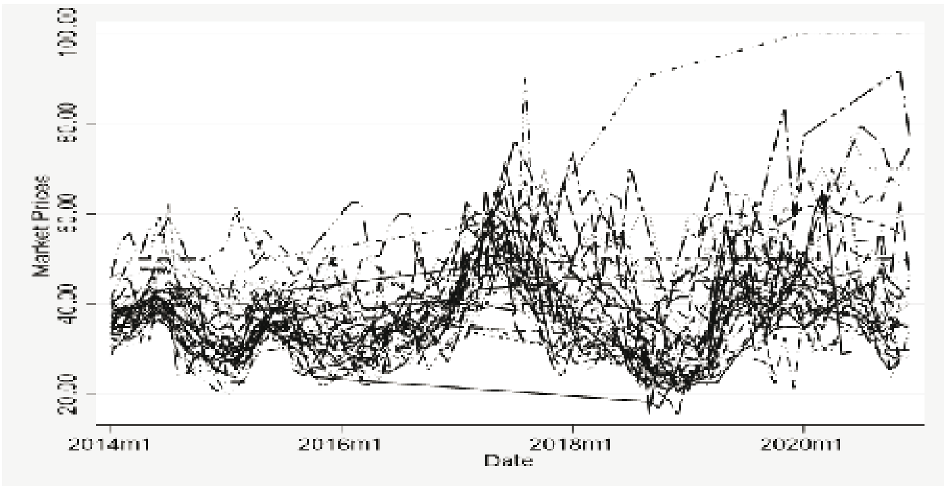
Figure 2: Box-and-Whisker plot of maize prices in markets across counties in Kenya, 2014–2020



Source: Compiled using market information from various issues of Leading Economic Indicators (2014-2020), Kenya National Bureau of Statistics (KNBS)

To further illustrate the trend and variability of maize prices, Figure 3 overlays price data for each county. From the graph, while there is co-movement of prices among some markets, the individual price trends of some markets indicate that some markets are not integrated.

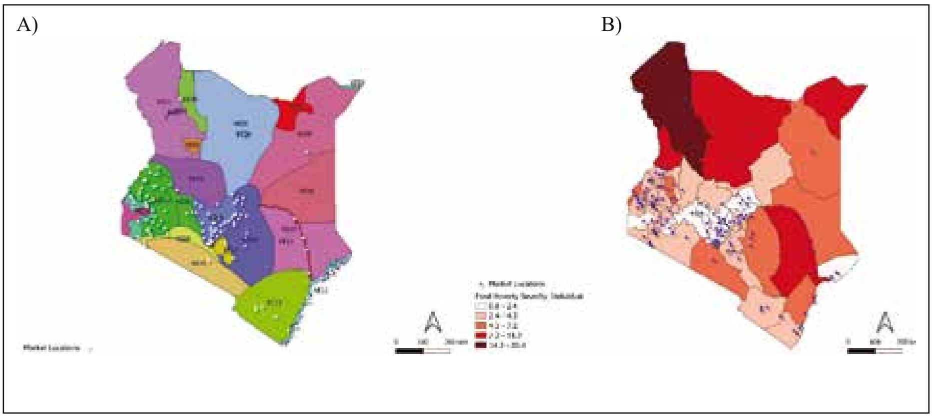
Figure 3: Trend of average monthly retail prices for dry maize in key markets across counties, 2014-2020 (per kg)



Source: Compiled using market information from various issues of Leading Economic Indicators (2014-2020), Kenya National Bureau of Statistics (KNBS)

Spatial patterns of market locations and the livelihood zones map (Figure 5.A) show that clustering of markets differs significantly by Kenya’s agro-ecological potential (see the livelihood map legend in Appendices 1). Markets for food purchases are poorly distributed in agro-ecological areas of low potential where market purchases are particularly important to meet food needs as most of the food commodities consumed by households are obtained from markets (KNBS, 2018). The observation is like the Livelihoods Zoning “Plus” Activity in Kenya by Famine Early Warning Systems Network (FEWS NET), where markets in lower productive zones are observed to be poorly distributed and often difficult to access.

Figure 4: Spatial variation of main maize markets, across: (A) Livelihood zones and (B) Food poverty mapping

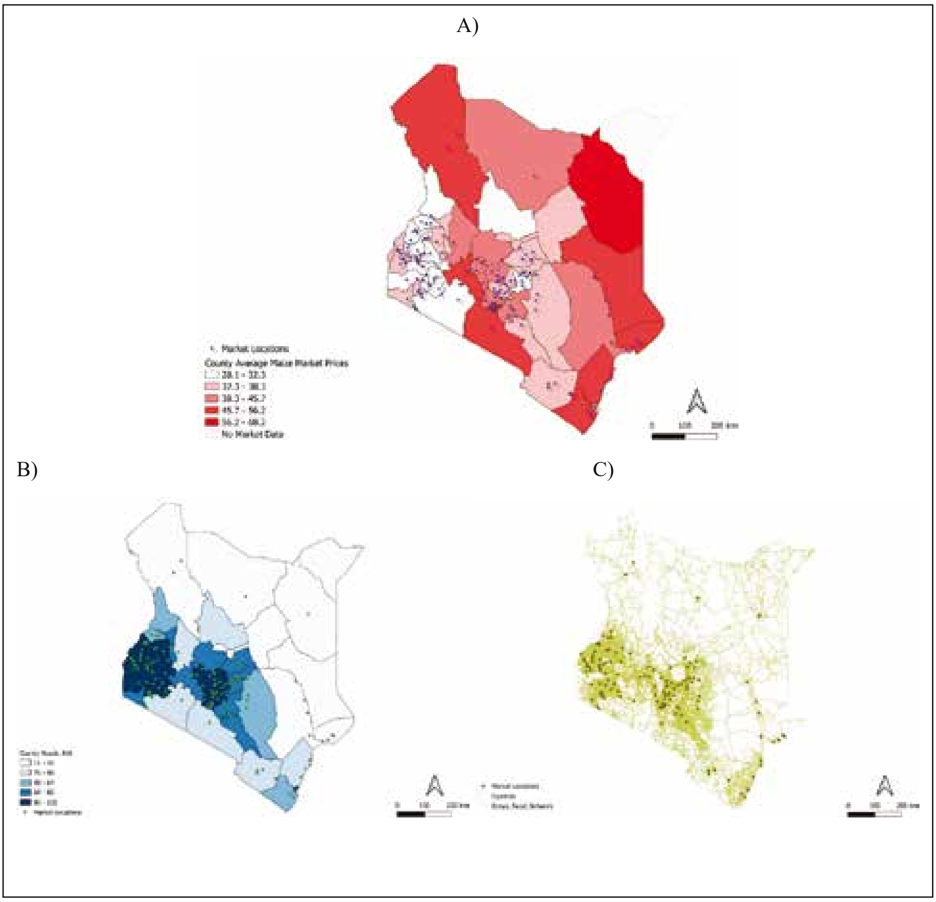


Source: Compiled using Market information from various issues of Leading Economic Indicators (2014-2020); Livelihood zone shapefile obtained from Famine Early Warning Systems Network (FEWS NET) website; and Food Poverty Severity Index as derived by the Kenya National Bureau of Statistics based on the 2015/16 Kenya Integrated Household Budget Survey (KIHBS)

Complementing spatial patterns of food poverty estimates (severity of food poverty at the individual level) by county shows that food poverty is more severe in areas with less clustering of food markets (Figure 5.B). The mapping provides important insights on the relationship between food poverty and trader concentrations and competition.

In Figure 5, the paper links market locations to market prices, Rural Access Index (RAI) and road network. As observed by Shin (2010), linking prices to market locations can enable one to assess the geography of market integration (Figure 5.A). Like Shin (2010), it is observed that locations with high prices are surrounded by markets with similar high prices. Conversely, areas with high maize markets are surrounded by markets with similar low prices. Further, market accessibility and connectivity are assessed by road infrastructure, which links markets to other markets and consumers/producers to markets (Mukeere, 2009). From the mapping of market locations to RAI and road network, the study observes spatial clustering of markets in areas within areas that have high scores of the RAI (Figure 5.B) and high connectivity road networks (Figure 5.C). The mapping gives an indication on the importance of road infrastructure on market accessibility and connectivity.

Figure 5: Spatial mapping of main maize markets along: (a) Average Prices; (B) County RAI; and C) Kenya Road Network



Source: Compiled using: Market information from various issues of Leading Economic Indicators (2014-2020); KRB road inventory geodatabase; and the 2019 RAI data from the Kenya Roads Board

4. Results and Discussion

4.1 Regression Analysis

Before carrying out the random effects panel analysis on maize price series, the study performed panel unit root tests to examine the time series properties of the dependent variable. The study implemented the Im-Pesaran-Shin, ADF-Fisher and PP-Fisher unit-root test for stationarity for all maize price series. The panel unit root tests lead to the rejection of the null hypothesis that the panels contain unit roots (see Appendix 4).

Table 2 shows the results from the estimation evaluating the effects of rural road infrastructure in maize prices. The study observes a strong autocorrelation in the monthly maize prices as a 1 per cent increase in prices in maize prices in a market contributes to a 0.726 per cent increase in maize prices in the subsequent month. The results suggest strong local persistence in maize prices as observed in similar studies in developing countries (Shively and Thapa, 2017; Le Cotty et al., 2017).

Table 2: Effects of rural road infrastructure on maize prices

Dependent Variable: ln_ Market Prices		
	Coef.	Robust Std. Err.
Lagged dependent variable (t-1)	0.726***	0.042
RAI	-0.00713***	0.002
ln_ Population Density	0.079***	0.024
Time trend	0.001***	0.000
ln_ USDKES(FD)	0.100	0.125
AgroZone (Base AgroZone1)		
AgroZone2	-0.070***	0.010
AgroZone3	-0.002	0.021

Months (Base January)[1]		
February	0.001	0.015
March	0.019	0.015
April	0.053***	0.013
May	0.052***	0.016
June	0.041**	0.017
July	0.003	0.014
August	-0.024	0.018
September	-0.032**	0.015
October	-0.012	0.016
November	-0.015	0.015
December	-0.015	0.016
Years (All) [2]	Yes	Yes
Counties (All) [3]	Yes	Yes
Constant	0.722	0.163

*p < 0.1, **p < 0.05, ***p < 0.01; 1. The month fixed effects are accounted for to capture how prices vary from one month to another 2 and 3. The regression model also controls for the year and county fixed effects by including a year categorical variable for all the years under consideration and county categorical variable for all the counties, respectively.

Turning to our main interest regarding transport costs, the effect of RAI on maize prices confirms a statistically significant reduction in prices in markets in areas that have high scores of the RAI. The estimation indicates that if we increase RAI by 1 unit, the study would expect maize prices to decrease by 0.713 per cent. The results are closely related to Aggarwal et al. (2018) where it is shown that in remote villages where markets are less likely to be with 10 km and one has to travel further to a maize market, transport costs increase maize prices. Similar results on the relationship of transport costs and food prices are found in Zant (2018), Shively and Thapa (2017) and Le Cotty et al. (2017).

Similar to observations by Baltenweck and Staal (2007) on human population density effects, proxy for local demand for commodities on food commodity prices in the country, the study observes that a 1 per cent increase in population density increases maize prices by 0.079 per cent. The positive time trend at monthly intervals reveals that, on average, the level of maize prices has significantly increased over time as observed from the time trend plots displayed in Appendix 3. In addition, similar to much of Sub-Saharan Africa (Aggarwal et al., 2018; Le Cotty et al., 2017), the results also indicate seasonal price variations in maize, with prices significantly positive in lean months and negative during the harvest season. Lastly, the agro-potential of an area has decreasing effects on maize prices. Three agro-ecological zones are identified from the driest to the wettest: AgroZone1-

Rainfall 400-800mm; AgroZone2- Rainfall 600-1,200mm; and AgroZone3- Rainfall 1,200-2,000mm. Maize prices decrease by 7 per cent in markets located in AgroZone2 compared to those in AgroZone1.

4.2 Markets Integration

Using the Moran's I, the study examines whether maize prices in every year (Shin, 2010) over the study period were clustered or not (Table 3). Moran's I is a test for spatial autocorrelation, and it evaluates how related the values of a variable are based on the locations where they were measured (Das and Ghosh, 2016).

Table 3: Moran's I statistic: Ln_average retail prices for dry maize

Moran's I Statistic: Ln_Average Retail Prices for Dry Maize					
Year	**Moran's I**	**E(I)**	**SE(I)**	**Z(I)**	**p-value**
2014	0.18079	-0.02632	0.0683	3.03214	0.002
2015	0.23823	-0.02564	0.06587	4.00616	0.000
2016	0.08828	-0.02703	0.06892	1.67299	0.094
2017	0.31152	-0.02857	0.07093	4.79502	0.000
2018	0.28544	-0.025	0.06243	4.97234	0.000
2019	0.10171	-0.025	0.0638	1.986	0.047
2020	0.05895	-0.02632	0.06567	1.29842	0.194

The results reject the null hypothesis of spatial randomization in all the years other than the year 2020. In the years 2014-2019, the p-value is statistically significant, and the z-score is positive. This indicates that the distribution of high values and/or low values of prices in the dataset are spatially clustered, an indication of market integration or the co-movement of maize prices between different markets. The low Moran's I value in 2020 is a possible indication of the geographic disintegration of local market linkages in the year because of the COVID-19 pandemic.

Having established presence of spatial autocorrelation, the study fits spatial autoregressive regressions accounting for spatial price relationships. Because of the requirement that data be strongly balanced in spatial autoregressive models for panel data, the regressions are also estimated for each year during the study period (Table 4).

Table 4: Spatial autoregressive (SAR) estimations

Dependent Variable: ln_ MarketPrices			
2014	Coef.	Std. Err.	P>z
Ln_populationdensity	0.028	0.024	0.249
RAI	-0.001	0.002	0.487
Agrozone (0=ASALs)	-0.153	0.074**	0.038
Constant	3.758	0.096***	0
Spatial lag of the dependent variable	0.056	0.133	0.672
Spatial autoregressive (SAR) error term	1.074	0.055***	0
2015			
Ln_populationdensity	0.046	0.028	0.101
RAI	-0.004	0.002**	0.043
Agrozone (0=ASALs)	-0.203	0.094**	0.031
Constant	3.726	0.115***	0
Spatial lag of the dependent variable	0.166	0.164	0.31
Spatial autoregressive (SAR) error term	0.957	0.027***	0
2016			
Ln_populationdensity	0.047	0.028*	0.096
RAI	-0.004	0.002**	0.042
Agrozone (0=ASALs)	0.024	0.076	0.756
Constant	3.646	0.088***	0
Spatial lag of the dependent variable	-0.020	0.037	0.584
Spatial autoregressive (SAR) error term	2.315	2.035	0.255
2017			
Ln_populationdensity	0.055	0.021***	0.009
RAI	-0.002	0.001	0.209
Agrozone (0=ASALs)	-0.115	0.062*	0.065
Constant	3.967	0.074***	0
Spatial lag of the dependent variable	-0.055	0.029*	0.059
Spatial autoregressive (SAR) error term	2.327	5.703	0.683
2018			
Ln_populationdensity	0.074	0.042*	0.079
RAI	-0.006	0.003**	0.047
Agrozone (0=ASALs)	-0.187	0.118	0.113
Constant	3.916	0.144***	0

Spatial lag of the dependent variable	-0.060	0.066	0.364
Spatial autoregressive (SAR) error term	3.004	1.706*	0.078
2019			
Ln_populationdensity	0.013	0.042	0.753
Rai	0.000	0.003	0.947
Agrozone (0=ASALs)	0.001	0.112	0.993
Constant	3.985	0.117***	0
Spatial lag of the dependent variable	-0.116	0.050**	0.02
Spatial autoregressive (SAR) error term	-0.238	0.712	0.738
2020			
Ln_populationdensity	0.069	0.043	0.108
RAI	0.000	0.003	0.878
Agrozone (0=ASALs)	-0.461	0.131***	0
Constant	4.070	0.100***	0
Spatial lag of the dependent variable	-0.072	0.040*	0.07
Spatial autoregressive (SAR) error term	-0.065	4.218	0.988

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

As noted by LeSage and Pace (2009), the magnitude of the SAR model estimates cannot be interpreted as done in the typical regression model fashion due to the presence of both direct and indirect impacts. For instance, if RAI improves, leading to a reduction in maize prices in a particular market, and that reduction in maize prices spills over to produce a further reduction in maize prices in another market, that reduction spill over to produce yet another reduction in prices in a different market and so on. The direct effect is the effect of the change within the county where the market is located, ignoring spillover effects. The indirect effect is the spillover effect.

However, the study can assess the signs and significant levels to determine the direction of the spatial impacts. As indicated by Saputro et al. (2019), spatial dependence is categorized into: (1) the spatial lag model; and (2) spatial error model.

The spatial lag model takes dependence in the dependent variable of a spatial unit and the corresponding neighbouring units into account. It considers the dependent variable on an area with other areas associated with it. The spatial error model considers spatial dependence in the error term of a spatial region and the corresponding neighbouring regions; that is, it accounts for the dependency of error values of an area with errors in other areas associated with it.

From Table 4, the study observes some level of spatial dependency in prices (the dependent variable) and error values. The study observes positive correlation between maize prices in one county and maize prices in the neighbouring county. The regression results indeed confirm the presence of market integration, though it is fluid from one year to another. These ties can be strengthened through transport networks between markets.

5. Conclusion and Policy Recommendations

5.1 Conclusion

Markets play a crucial role in achieving food security by diversifying food supply and compensating food supply deficits. However, the functioning and vibrancy of agricultural markets depends on inclusive and efficient delivery channels of food commodities. In Kenya, like much of Sub-Saharan Africa, market access varies largely across space, and one of the major reasons attributed to this are transport costs. Investments in transport infrastructure has the potential of resolving transaction costs constraints faced by market actors while accessing markets. With most of the county governments in Kenya relying on agriculture as a key driver of their economies, and given the essential role of markets in achieving SDGs 1 and 2, investment priorities towards improved access to markets may need to be re-evaluated.

In particular, the relationship between key transport infrastructure in counties and food prices that could potentially affect food security need to be evaluated. This study aims at increasing understanding of the opportunities related to investments to decrease gaps in road infrastructure, particularly in rural areas, on maize retail prices.

Using trend analysis and spatial mapping, the geographical dynamics of market integration are illustrated, though it is highly localized. While there is co-movement of prices among some markets, the individual price trends of some markets indicate that some markets are not integrated. Markets are observed to be highly clustered in areas with high agro-ecological potential and better road infrastructure. Food poverty is also depicted to be more severe in areas with less clustering of food markets.

To shed more light on the role of road infrastructure on maize retail prices, results from empirical estimations establish that improvement in road infrastructure, measured by Rural Access Index (RAI), reduces maize prices in retail markets, which are central to achieving food security among households. Further, using spatial analysis, the study evaluates presence of spatial dependence in maize prices between one county and neighbouring counties, which can be strengthened through transport networks between markets.

5.2 Policy Recommendations

The research demonstrates the potential of transport policies in eradicating food poverty by:

1. Reducing marketing costs, which strongly influence the price level, and increase with poorer rural road network.
2. Strengthening the link between markets, promoting local integration, thereby smoothing commodity prices

Counties should establish investment priorities for improving rural access, as measured by the Rural Access Index (RAI), without which it will be difficult to have broad-based and low costs to markets necessary to eradicate hunger.

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Appendices

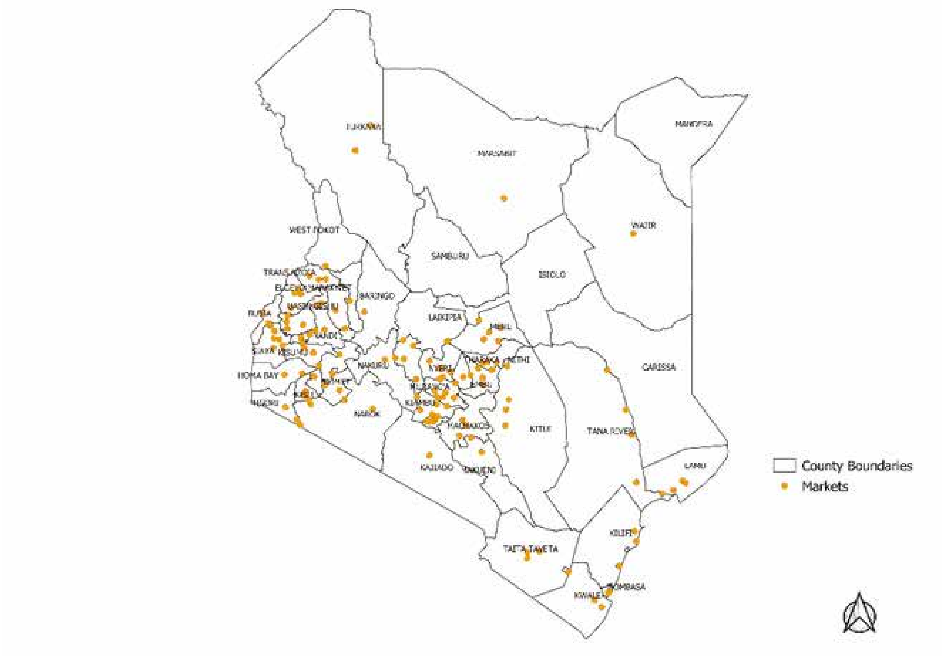
Appendix 1: Kenya's Livelihood zone map legend

KE01 - Northwestern Pastoral Zone
KE02 - Turkwell Riverine Zone
KE03 - Northwestern Agropastoral Zone
KE04 - Lake Turkana Fishing Zone
KE05 - Northern Pastoral Zone
KE06 - Marsabit Marginal Mixed Farming Zone
KE07 - Northeastern Agropastoral Zone
KE08 - Mandera Riverine Zone
KE09 - Northeastern Pastoral Zone
KE10 - Eastern Pastoral Zone
KE11 - Southeastern Pastoral Zone
KE12 - Coastal Medium Potential Farming Zone
KE13 - Coastal Marginal Agricultural Mixed Farming Zone
KE14 - Tana Riverine Zone
KE15 - Southern Pastoral Zone
KE16 - Southeastern Marginal Mixed Farming Zone
KE17 - Southeastern Medium Potential, Mixed Farming Zone
KE18 - Southern Agropastoral Zone
KE19 - Central Highlands, High Potential Zone
KE20 - Western Medium Potential Zone
KE21 - Western High Potential Zone
KE22 - Western Lakeshore Marginal Mixed Farming Zone
KE23 - Lake Victoria Fishing Zone
KE24 - Western Agropastoral Zone

International Boundaries
Districts
Lakes
Capital
Cities

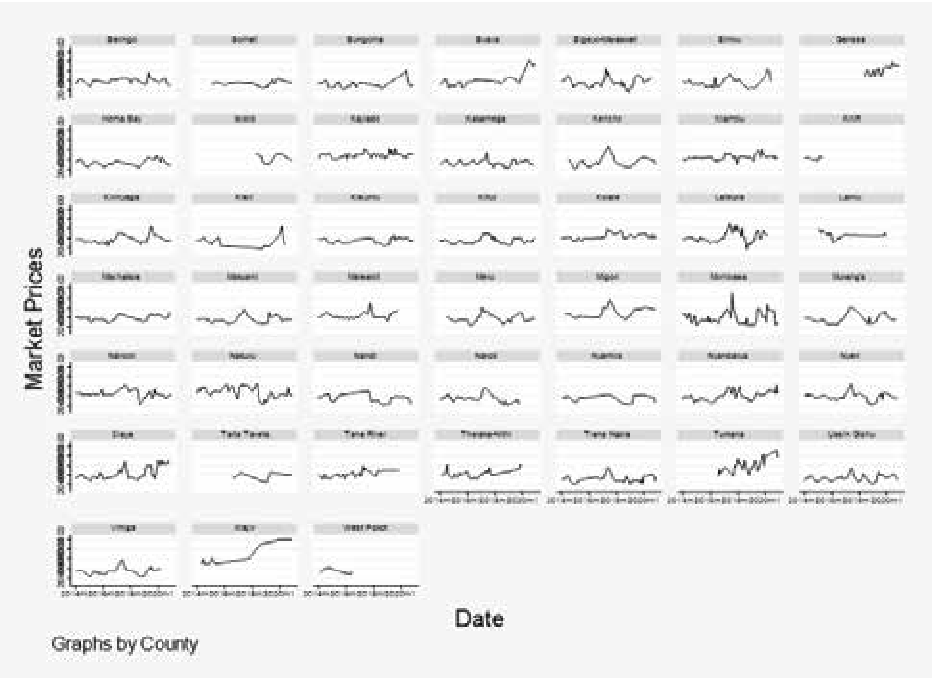
Source: Famine Early Warning Systems Network (FEWS NET) website

Appendix 2: A map of key markets across counties in Kenya



Source: Compiled using market information from various issues of Kenya National Bureau of Statistic (KNBS), Leading Economic Indicators (2014-2020)

Appendix 3: Maize trends across counties between January 2014 and December 2020



Appendix 4: Unit root test on maize price series

Unit Root Tests				
1. Im-Pesaran-Shin unit-root test				
H0: All panels contain unit roots	Levels	First Difference		
Variables	Statistic	p-value	Statistic	p-value
ln_Ksh/US$ Exchange Rate	-0.8698	0.1922	-90.0397	0
ln_MarketPrices	-8.8478	0		
2. Fisher-type unit-root test				
H0: All panels contain unit roots				
Based on augmented Dickey-Fuller tests				
	Levels	First Difference		
Variable: ln_MarketPrices	Statistic	p-value	Statistic	p-value
Inverse chi-squared (90)	379.3935	0		
Inverse normal	-12.9499	0		
Inverse logit t (229)	-14.997	0		
Modified inv. chi-squared	21.5701	0		
Variable: ln_Ksh/US$ Exchange Rate	Statistic	p-value		
Inverse chi-squared (90)	68.6387	0.9543	1372.933	0

Inverse normal	-0.5652	0.286	-33.7857	0
Inverse logit t (229)	-0.4985	0.3093	-56.5429	0
Modified inv. chi-squared	-1.5922	0.9443	95.6242	0
Based on Phillips-Perron tests				
	Levels	First Difference		
Variable: ln_MarketPrices	Statistic	p-value	Statistic	p-value
Inverse chi-squared (90)	348.1611	0		
Inverse normal	-9.845	0		
Inverse logit t (229)	-12.2779	0		
Modified inv. chi-squared	19.2422	0		
Variable: ln_Ksh/USD Exchange Rate				
Inverse chi-squared(90)	118.8509	0.0225	3243.929	0
Inverse normal	-4.1722	0	-54.5101	0
Inverse logit t(229)	-3.7435	0.0001	-133.598	0
Modified inv. chi-squared	2.1504	0.0158	235.08	0

*we let xtunitroot choose the number of lags for each panel by minimizing the AIC

*possible cross-sectional correlation is removed by specifying the demean option

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