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SERA Policy Research Brief

Cross-Border Transmission of Food Price Shocks[1]

Food price volatility has a profound impact on the lives of the poor in developing countries, but much remains to be learned about the sources of food price volatility. Food prices may be influenced by internal factors such as supply shocks or external factors such as demand shocks emanating from neighboring countries or world markets. The influence of external factors is commonly assumed to be transmitted from one external, typically international, market to the largest domestic city or port. This Policy Research Brief reports the results of research that aims to better understand the cross-border transmission of demand shocks using a network approach that identifies the sources of price volatility for 18 regional maize and rice markets in Tanzania.

The findings have important trade policy implications. If shocks to domestic food markets are transmitted through Dar es Salaam, then border controls will be more effective at controlling food price volatility than if shocks are transmitted from regional sources through more informal trade channels such as across land borders and lakes. Further, understanding the channels through which regional food market disturbances are transmitted to local Tanzanian markets will serve to improve forecasts of domestic food price volatility. The research concluded that Dar es Salaam is not a demand or supply focal point and that most external demand shocks to the domestic maize and rice market do not emanate from or go through Dar es Salaam. This suggests that border controls that are primarily directed at imports coming through the port in Dar es Salaam will not be very effective at controlling food price volatility.

[1] This Policy Research Brief is based on a working paper entitled "The Cross-Border Transmission of Price Shocks: Evidence from Tanzanian Food Markets" co-authored by John Baffes, Varun Kshirsagar and Donald Mitchell. The research was supported by the Tanzania SERA Policy Project. The authors are respectively, Senior Economist at the World Bank, independent consultant, and Senior Advisor of the Tanzania SERA Policy Project. The working paper is available from authors by email at: jbaffes@worldbank.org, varun.kshirsagar@gmail.com and don.mitchell09@gmail.com. The Tanzania SERA Policy Project is a USAID-funded Feed the Future Project that seeks to improve agricultural policies in Tanzania and build capacity for policy analysis and advocacy. It is implemented by Booz Allen Hamilton.

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Dar es Salaam does not connect the main surplus producing areas (i.e. the southern zone for maize and rice, and the lake zone for rice) with the main regional demand centers of Nairobi (Kenya) in the north and Nampula (and the rest of Mozambique) in the south and much of this trade is through informal channels. That limits the effectiveness of protectionist trade policies since informal trade is more difficult to control than trade through major ports such as Dar es Salaam. In particular, Songea (for maize) and Shinyanga (for rice) are focal points for local price formation, and these markets are influenced by other markets in the region. For maize markets, Nairobi has the largest influence on Tanzanian markets during the harvest season, while Nampula has the largest influence during the lean season. For rice, Bukoba (an important Lake Victoria port) has the largest influence during the harvest season, while international markets (Vietnam and Pakistan) have the largest influence during the lean season.

These findings suggest a more effective policy than trying to control cross-border food movements would be to remove impediments to food flows within the country. While Dar es Salaam is the largest city and economic capital of the country, the demand from Kenya and Mozambique are more significant determinants of prices and policy makers need to be aware of the policies of neighboring countries when formulating a national food trade policy. The main policy message from this Policy Research Brief is that border controls for maize and rice are not likely to be an effective way to provide improved price incentives to producers because demand shocks are primarily transmitted through informal channels from neighboring countries. Other measures such as reducing inefficiencies that stem from inadequate rural infrastructure are likely to be more effective at increasing agricultural productivity.

The Estimation Framework

The empirical framework for the research (which is described in the full paper) builds on the framework employed in Baffes et al. (2015) and consists of a bilateral vector error correction model (Engle and Granger (1987)) with additional controls for seasonality, weather anomalies and export bans (maize). Let p_t^A and p_t^B be the real log prices, at time t, for the relevant commodity (maize or rice) for a pair of markets A and B that experience local weather anomalies $NDVI_t^A$ and $NDVI_t^B$ then equations 1-3 comprise the main specification:

$$\Delta p_t^A = \mu^A + \gamma_1^A(p_{t-1}^B - p_{t-1}^A) + \gamma_2^A \Delta p_{t-1}^B + \gamma_3^A \Delta p_{t-1}^A + F_t[\bullet] + u_t^A \quad (1)$$

$$\Delta p_t^B = \mu^B + \gamma_1^B(p_{t-1}^B - p_{t-1}^A) + \gamma_2^B \Delta p_{t-1}^B + \gamma_3^B \Delta p_{t-1}^A + F_t[\bullet] + u_t^B \quad (2)$$

$$F_t[\bullet] = \gamma_4^{S1} \sin\left(\frac{2\pi t}{12}\right) + \gamma_4^{C1} \cos\left(\frac{2\pi t}{12}\right) + \gamma_4^{S2} \sin\left(\frac{4\pi t}{12}\right) + \gamma_4^{C2} \cos\left(\frac{4\pi t}{12}\right) + \gamma_5^A NDVI_t^A + \gamma_5^B NDVI_t^B + \gamma_6 I_{BAN_t} \quad (3)$$

This empirical framework has two main advantages. First, it is the simplest approach to estimate whether a market is endogenous or exogenous in a given relationship. Second, in contrast to a framework with several (potential) co-integrating vectors, the framework provides flexibility in terms of specification choices to incorporate additional variables, and may therefore control for harvest cycles and other local factors. Together, this allows for better interpretations of the economics underlying the parameter estimates.

More specifically, if a market adjusts to the lagged spread between the co-integrated series, it is considered to be the endogenous (i.e. a follower) market with regard to that pair. If it doesn't adjust, it is considered exogenous (i.e. the lead market). Our core insight, with regard to market network analysis, is to use these estimated values to calculate recursive measures of a market's importance to the domestic food market system. For example, Arusha and Moshi are important exogenous rice and maize markets not just because prices in many other markets adjust to their lagged price differential, but because the markets that do adjust are, in turn, exogenous (i.e. lead markets) in relationships with other markets, and so on. Consequently, shocks to Arusha and Moshi (markets closest to Kenya) exert a strong influence across both maize and rice systems. Therefore, they capture

the main channel through which external demand shocks influence the Tanzanian maize and rice market systems.

Rice and Maize Markets in Tanzania

Tanzania's geography is important in understanding its food staples markets. First, the largest city (Dar es Salaam) does not connect the major rice or maize producing zones with major regional demand centers to the north (Kenya) or to the south (Mozambique). Consequently, it does not serve as a major hub with regard to the road transport of food staples across countries in the region. Surplus food from the south would plausibly flow through Iringa and Dodoma into Kenya and Uganda. Second, while road transport links to Kenya (between Arusha/Moshi and Nairobi) as well as water transport routes across Lake Victoria are relatively well developed, the transport linkages to Tanzania's south are less well developed. Third, the number of possible paths for food trade is large, and it would be difficult to monitor and control food flows across all of Tanzania's land and water borders.

Rice and maize markets have significant structural differences in production, consumption and trade (Table 1). While consumption and production of both have increased rapidly, Tanzania produces a small surplus of maize in most years but is often deficit in rice. Almost all Tanzania's neighboring countries are heavily dependent on rice imports (typically from more efficient producers in Asia), and cannot regularly rely on imports from Tanzania. In contrast, most countries (with the important exception of Kenya) are close to being self-sufficient in maize. Table 1 has three implications for Tanzanian maize markets and trade. First, Kenya is the major deficit country in the region. Kenya imports about a sixth of its consumption, which is the largest in East Africa (3.6 million metric tons). Second, Kenya's maize import needs are growing rapidly. In contrast, Mozambique has reduced its need for imported maize. Third, all of Tanzania's neighbors produce significant quantities of maize. This provides the potential for trade as an instrument to diversify shocks to maize production that are not correlated across countries. In contrast, the potential for trading rice with Tanzania's neighbors is more difficult. Together, this suggests the need to develop a commodity-specific food trade policy that is cognizant of market demand and supply for all the bordering countries — both during favorable and less favorable years.

Table 1: Maize and Rice Balances in Eastern and Southern Africa (000 tons).

	Consumption			*Production*			*Net Imports*		
	2002-08	*2009-15*	*% Ch*	*2002-08*	*2009-15*	*% Ch*	*2002-08*	*2009-15*	*% Ch*
Maize Market									
Kenya	2,921	3,621	24.0	2,742	2.989	9.0	0.08	0.17	8.8
Mozambique	1,457	1,686	15.7	1,282	1,589	24.0	0.13	0.06	-7.0
Rwanda	107	564	426.0	107	502	367.6	0.02	0.13	10.5
Tanzania	3,100	4,771	53.9	3,119	5,085	63.1	0.01	-0.04	-5.4
Uganda	1,179	2,386	102.4	1,222	2,589	112.0	-0.03	-0.08	-4.4
Zambia	1,057	2,214	109.5	1,104	2,732	147.5	0.05	0.00	-5.3
Rice Markets									
Kenya	280	462	65.1	33	70	114.8	0.94	0.83	-10.0
Mozambique	464	614	32.4	126	176	40.2	0.73	0.71	-1.60
Rwanda	48	92	91.4	34	53	56.7	0.30	0.43	12.7
Tanzania	877	1,520	73.4	761	1,401	84.0	0.13	0.08	-5.3
Uganda	141	207	46.9	97	144	49.1	0.31	0.30	-4.4
Zambia	19	38	96.0	9	31	232.7	0.52	0.19	-5.3

Sources: Author's estimates based on USDA PSD database.

Table 2 describes the salient characteristics of maize prices in Tanzanian and relevant external markets. The international benchmark prices (U.S. Gulf and Randfontein, South Africa) are considerably lower than the prices in markets in Eastern and Southern Africa. Maize price levels are the highest in the major deficit areas of Nairobi, Mombasa and Maputo and lowest in the surplus areas. For Tanzania, prices are lowest in the Southern Highlands. Songea, a remote surplus market in the Southern Highlands, has the lowest average price level of any market in Tanzania. Crucially, the markets with which Songea and the other southern markets may engage in cross-border trade (Kasama, Zambia; Mzuzu, Malawi; and Nampula, Mozambique), also have low price levels because they share the same characteristics as Songea. Of these, Nampula is the best connected and has the lowest surpluses, and it exerts an influence on the southern Tanzanian markets, and by extension to the entire Tanzanian maize market system. Finally, it is worth emphasizing that the markets with the lowest (average) price levels also exhibit the greatest declines during the harvest, as well as the largest volatility.

Table 3 describes the main characteristics of rice prices across the main regional markets in Tanzania. The main production areas (Shinyanga, Mwanza, Tabora, and Mbeya) have the lowest prices, and the highest price volatility. The seasonal declines are comparable to those in the surplus maize producing areas, and prices during the harvest period are comparable to international prices. In contrast, price levels across Tanzania in March (the peak of the lean season) are considerably higher than international prices. Thus if the goal of a protectionist rice policy is to support the development of the rice industry, then the prices that matter are surely the ones in the main producer regions during the harvest. But what these results show is that prices are not higher than international prices during the harvest period in the main producing areas while prices are higher than international prices during the lean period prior to harvest. Thus the policy does not effectively support the development of the rice industry, but it does increase costs to consumers.

Table 2: Maize Price Levels and Volatility in Local, Cross-Border and International Markets

	Mean Real Price (2010 Tsh.) : 2004-2015			Volatility (%)
Market	Full Sample	March (Pre-Harvest)	July (Main Harvest)	Std. Dev. of Real Log Changes
Arusha	34,697	36,061	33,258	9.7
Bukoba	36,687	33,106	37,137	11.6
Dar	36,254	37,785	35,037	9.9
Dodoma	36,929	40,288	33,802	10.1
Iringa	28,326	32,493	26,440	13.4
Lindi	36,823	43,248	32,935	16.8
Mbeya	28,958	31,836	25,858	10.4
Morogoro	35,666	39,586	31,002	13.5
Moshi	36,168	36,644	37,305	10.7
Mtwara	36,128	41,673	31,739	17.6
Musoma	38,527	36,408	37,202	11.6
Mwanza	40,098	40,162	39,825	10.4
Shinyanga	36,275	38,705	34,181	10.4
Singida	34,536	37,272	31,802	12.3
Songea	24,746	29,296	21,299	17.7
Sumbawanga	24,947	24,515	22,281	14.1
Tabora	35,002	38,934	30,617	13.5
Tanga	34,386	36,711	30,788	14.1
Median	**35,897**	**36,991**	**32,368**	**12**
Neighboring Countries				
Kampala	31,404	30,287	34,488	15.7
Nairobi	41,220	39,117	43,387	9.4
Mombasa	40,962	38,821	45,086	9.3
Nampula	37,608	42,630	32,628	14.3
Maputo	50,154	51,610	47,483	9.8
Kasama	33,000	39,959	28,696	19.6
Lilongwe	36,229	31,630	34,832	17.2
Mzuzu	33,850	41,357	29,541	16.3
International Benchmarks				
Randfontein	28,844	29,123	28,729	9.1
US Gulf	25,977	26,244	26,647	6.8

Source: Authors' estimates based on data from the Government of Tanzania and FAO (GIEWS)

Table 3: Rice Price Levels and Volatility in Local, Cross-Border and International Markets

	Mean Real Rice Price (2010 TSh.) : 2004-2015			Volatility (%)
Market	Full Sample	March (Pre-Harvest)	July (Main Harvest)	Std. Dev. of Real Log Changes
Arusha	103,503	107,703	100,248	5.3
Bukoba	91,331	93,521	83,695	9.5
Dar	106,049	116,249	100,183	7.2
Dodoma	110,650	113,706	104,810	7.8
Iringa	101,271	109,421	94,589	8.5
Lindi	108,482	115,479	100,697	7.6
Mbeya	97,953	105,273	92,243	8.8
Morogoro	98,573	104,926	92,762	7.2
Moshi	106,289	106,252	104,027	8.6
Mtwara	103,874	112,126	94,697	7.3
Musoma	98,891	103,529	89,781	8.7
Mwanza	92,747	100,745	84,255	9.8
Shinyanga	89,256	95,865	78,702	10.0
Singida	102,145	110,812	91,273	8.1
Songea	96,108	100,108	90,088	7.8
Sumbawanga	90,961	98,998	81,404	10.3
Tabora	87,288	93,951	77,846	8.7
Tanga	101,227	107,688	95,586	5.4
Median	**100,059**	**105,763**	**92,503**	**8**
Neighboring Countries				
Kampala, Uganda	108,814	107,191	108,240	7.7
Kenya : Grade 1	210,299	203,942	212,735	8.8
Kenya : Grade 2	107,398	104,035	108,625	5.3
Nampula, Moz.	61,962	60,782	62,716	3.6
Maputo, Moz.	60,808	60,074	59,991	4.0
International Benchmarks (High Quality)				
Pakistan Basmati	79,809	80,546	82,573	7.4
Thailand (100%)	75,112	74,943	75,946	4.9

Source: Authors' estimates based on data from the Government of Tanzania and FAO (GIEWS)

Cross Border Linkages

Cross border external linkages are reported for maize in Table 4a and rice in Table 4b in terms of the number of Tanzanian markets that are affected by external markets and the speed of adjustment of prices to shocks to these markets (half-lives). These cross border external linkages are different for the harvest and lean periods. For example, demand shocks to Nairobi are transmitted to 12 Tanzanian markets during the harvest season with a half-life of 2.1 months, but only 4 Tanzanian markets during the lean season with a half-life of 3 months. This is consistent with the trade balances reported in Table 1 and also with popular belief. However, the maize market in Nairobi is also influenced by markets in Tanzania (albeit with a much larger half-life of 5 months). No external market exerts a large influence on any domestic rice market. In contrast, several external maize markets strongly influence domestic prices. Further, the half-lives are much larger with respect to the linkages with external rice markets.

Table 4a: External Maize Market Influences.

	Harvest Season				Lean Season			
	Influenced Tanzania		Influenced by Tanzania		Influenced Tanzania		Influenced by Tanzania	
	No.	HL	No.	HL	No.	HL	No.	HL
External Market								
Kampala, Uganda	0		3	2.9	7	3	0	
Nairobi, Kenya	12	2.1	9	5.0	4	3	0	
Mombasa, Kenya	7	2.0	0		6	2	0	
Nampula, Mozambique	9	2.2	7	3.8	15	1	1	3
Kasama, Zambia	0		0		5	2	6	2
Lilongwe, Malawi	3	2.8	0		11	2	0	
Mzuzu, Malawi	6	2.8	0		5	3	17	4
Randfontein, SA	6	4.6	0		2	4	0	
U.S. Gulf	5	3.6	0		1	4	0	

Source: Baffes, Kshirsagar, and Mitchell (2016).
Note: HL refers to Half Life which is the number of months required for one-half of the price differential to be eliminated.

Table 4b: External Rice Market Influences.

	Harvest Season				Lean Season			
	Influenced Tanzania		Influenced by Tanzania		Influenced Tanzania		Influenced by Tanzania	
	No.	HL	No.	HL	No.	HL	No.	HL
External Market								
Kampala, Uganda	1	2.7	6	3.8	1	4.5	11	5.6
Kenya, Grade 1	0		0		1	7.2	0	
Kenya, Grade 2	0		0		1	5.6	0	
Nampula, Mozambique	2	6.9	0		1	7.8	0	
Pakistan Basmati	1	7.8	0		1	7.1	0	
Pakistan 25% Broken	2	8.3	0		0		0	
Thailand 100%	1	4.3	0		0		0	
Thailand 5% Broken	2	8.2	0		0		0	
Thailand 25% Broken	2	7.7	0		0		0	
Vietnam 5% Broken	2	8.6	6	1.8	1	9.0	0	
Vietnam 25% Broken	2	8.7	3	13.1	2	9.1	0	

Source: Baffes, Kshirsagar, and Mitchell (2016).
Note: HL refers to Half Life which is the number of months required for one-half of the price differential to be eliminated.

Perhaps less well known is the important influence of Nampula, Mozambique. While Nampula also exerts an influence on local Tanzanian markets during the Tanzanian harvest, it is the primary external maize market during the lean season. Nampula influences 15 local Tanzanian maize markets (with a minimum half-live of just 1.8 months) during the lean season. Differences in harvest cycles may explain this pattern. First, the Tanzanian lean season in the main surplus areas (October through March) overlaps with the main Kenyan harvest season

(which begins in September). Therefore, demand for maize from Kenya (and Northern Tanzania) will be small during these months. In contrast, the lean season in the Tanzanian Southern Highlands corresponds to the lean season in Mozambique and Zambia. Further, Tanzania typically has larger surpluses than these countries. Therefore, during the lean season Nampula serves as a conduit to link surplus from Southern Tanzania to countries in Southern Africa.

Tanzanian maize prices do not influence international markets (U.S. Gulf) for maize or the maize prices in South Africa. Although, a little less than half the Tanzanian markets are influenced by the U.S. Gulf and South Africa, the minimum half-lives are significantly larger than those associated with Nairobi and Nampula. It is especially worth noting that cross-border adjustments with Kenya and Mozambique are comparable with domestic adjustments, while trade frictions with the international markets are larger. This suggests that road (and perhaps Lake) transport works well, but trade flows through the sea ports have to overcome greater impediments.

In contrast to maize, external-domestic linkages for rice are particularly weak. While we do not have rice prices for Nairobi, Kenyan average prices are weakly linked with Tanzania. Asian markets influence very few domestic Tanzanian rice markets and with large half-lives typically between 6 and 8 months. There are three reasons for these weak linkages. First, rice markets are protected with large import tariffs. Second, none of Tanzania's neighbors produce a rice surplus, but most import rice with lower tariffs. Consequently, prices are lower in these countries and exports to Tanzania are discouraged. Therefore, regional trade flows with other countries in the region are typically informal and not significant enough to engender a fast adjustment. Third, when Tanzania does officially import rice from Asia, the time and trade costs are considerable (including contracts, ocean transport and bottlenecks at the ports).

Market Network Analysis

The previous analysis examined price relationships between market pairs. Yet, in the real world, markets operate as part of a system. Therefore, it is important to examine individual markets in the context of their systemic influence. To begin with, we define market linkages based on three criteria. First, a given market pair is required to be co-integrated-in the sense that the price level series have unit roots, but the spread is stationary. Second, the relevant adjustment parameter is required to be significant at the one percent level. Third, the linkages are allowed to vary by commodity and season.

We then use these market linkages to generate a matrix of market linkages that forms a network. Further, we normalize each row so that it is equal to one. Finally, we employ the PageRank measure (Brin and Page (1998)) as our preferred estimate for a market's systemic influence. The PageRank provides a higher score to markets that exert a greater influence on the system. We use PageRank estimates because a given market's systemic influence is based not just on the number of markets it influences, but also on the influence that those markets exert on other markets in the system, and so on in a recursive fashion.

Figures 1 and 2 show the network of market linkages for domestic maize markets and relevant external markets. The size of the node corresponds to its PageRank (see full paper for details). The external markets are shown in red, while domestic markets are in gray. During the harvest season, Nairobi is the focal market for demand shocks. However, Nampula is an important source for demand shocks during the maize harvest, and the primary external market during the lean season. Nampula is linked to the ports of Lindi, Dar es Salaam and Tanga, but most importantly also linked with all the markets in the Southern Highlands.

Figure 3 shows the corresponding rice market network during the harvest season. Bukoba (a Lake Victoria port) is 7 times as influential as Dar es Salaam during the harvest — which speaks to the importance of demand from Kenya and Uganda. These markets adjust to markets that in turn adjust to other markets. Figure 4 shows that demand shocks to the rice market network, during the lean season originate in Asia – although, officially tariffs are high, and imports from Asia are intermittent.

Figure 1: The Domestic Maize Market System During the Harvest Season

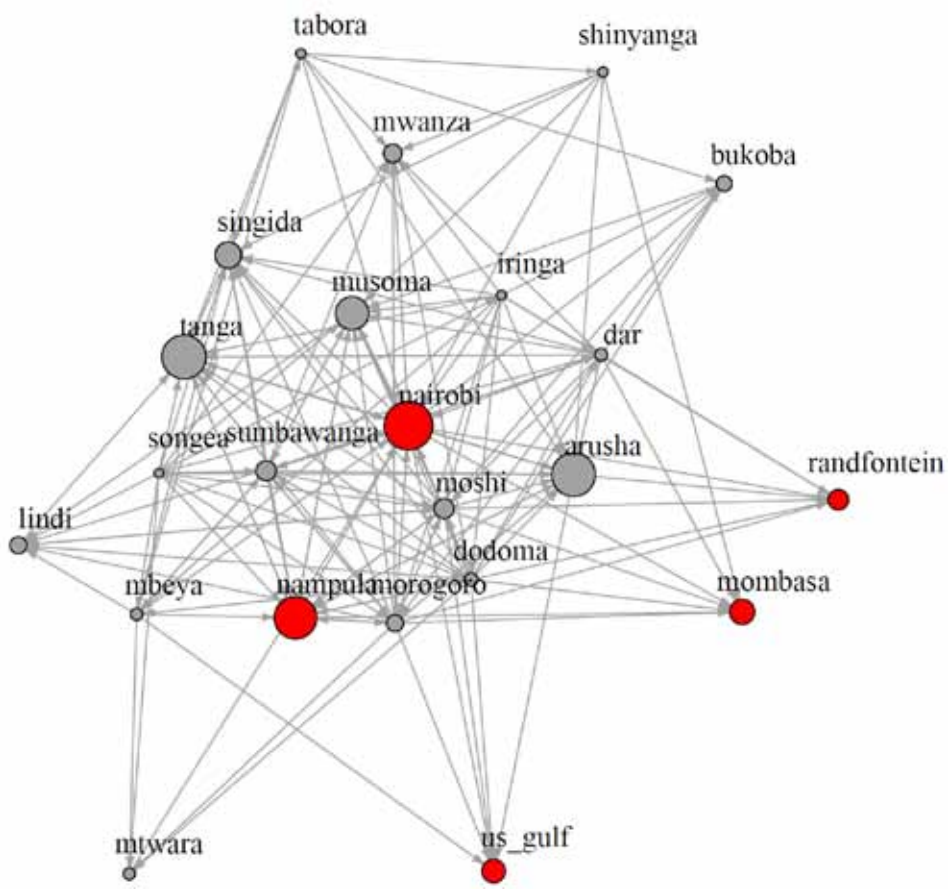


Figure 2: The Domestic Maize Market System During the Lean Season

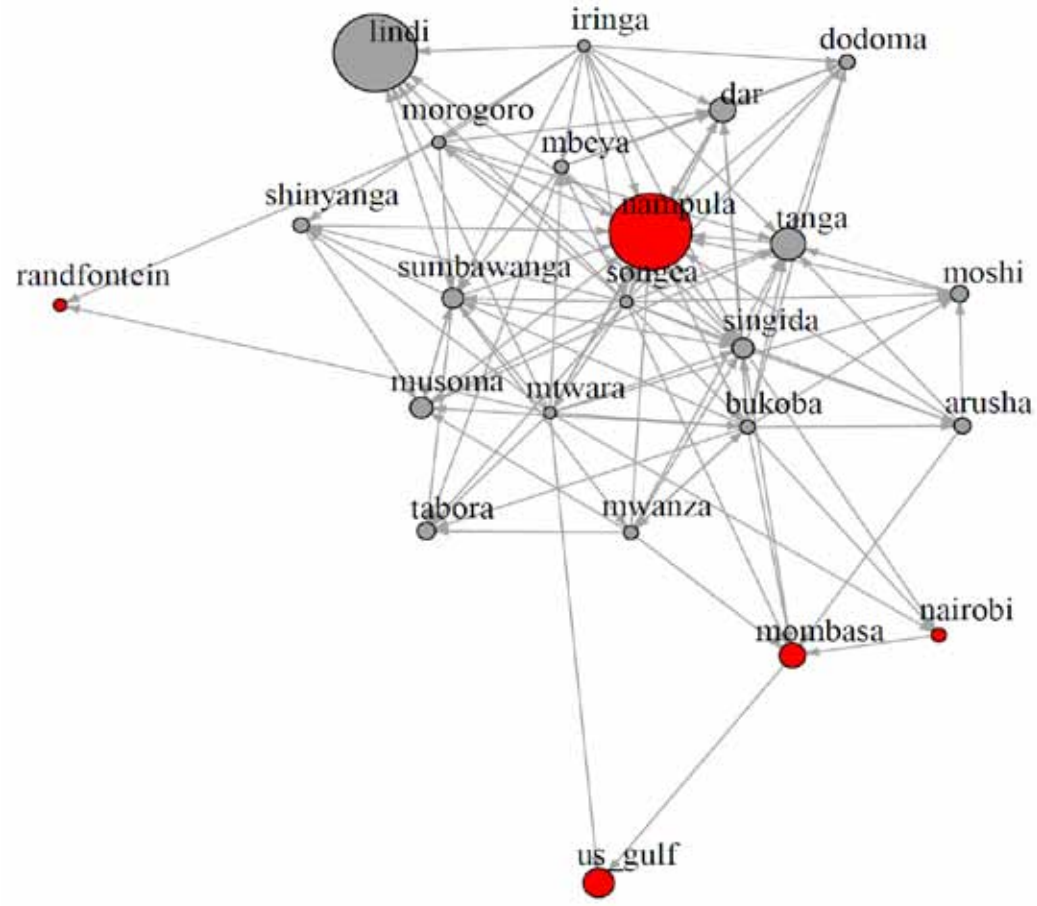


Figure 3: The Domestic Rice Market System During the Harvest Season

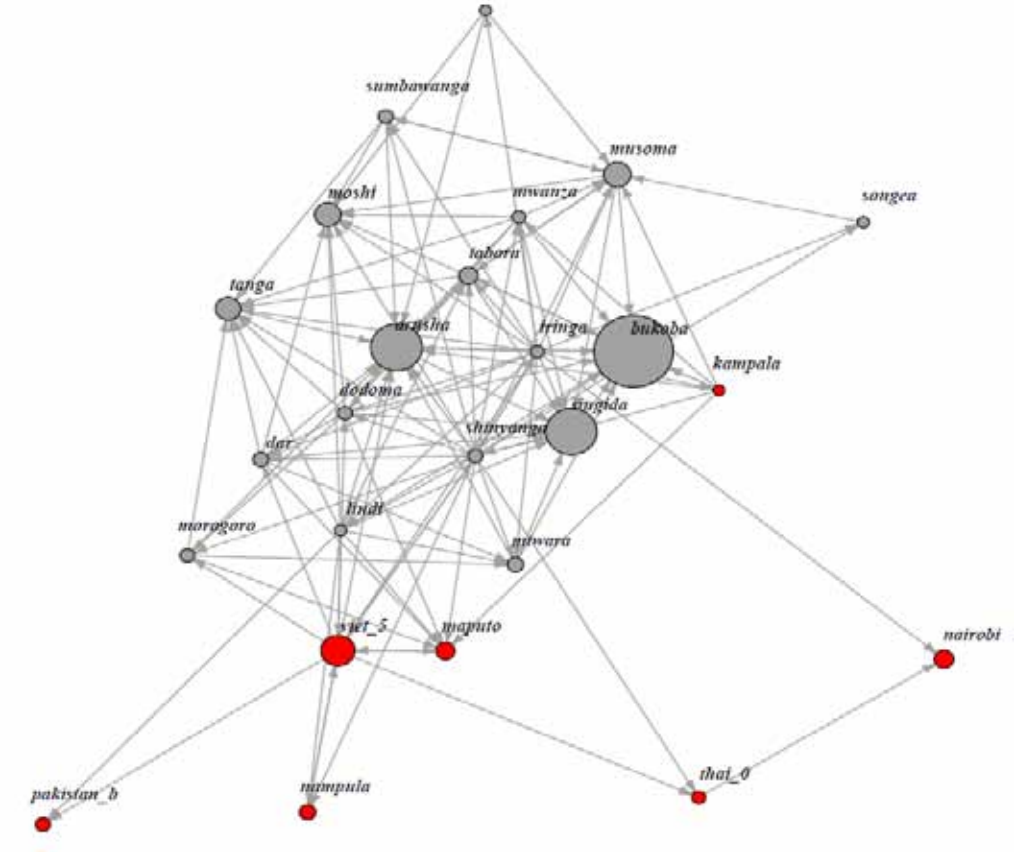
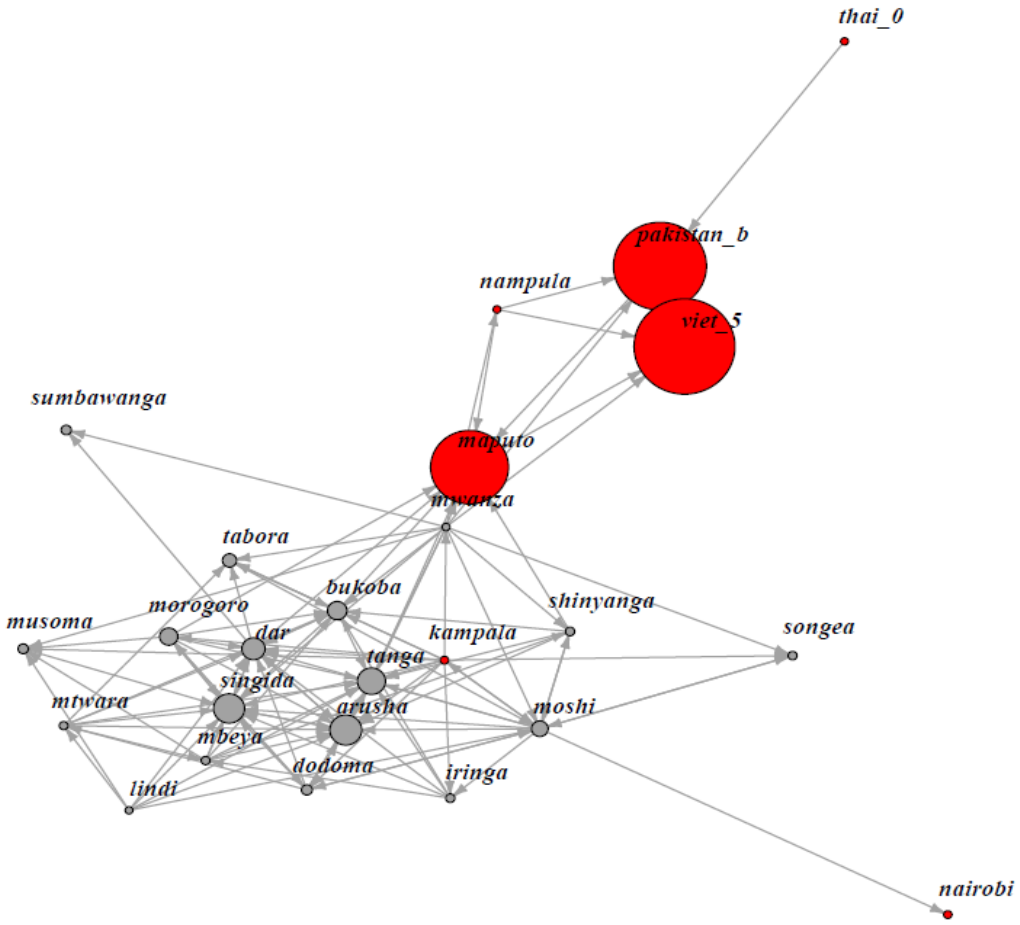


Figure 4: The Domestic Rice Market System During the Lean Season



Conclusion

This Policy Research Brief shows that the sources of exogenous demand shocks to local food markets originate outside Tanzania. It also shows that markets in areas most suitable for crop production are the ones that are also most vulnerable to systemic shocks. Consistent with these results, price levels are the lowest and volatility is the highest in these areas. This is true for both maize (which has been subjected to frequent export bans and therefore has a negative net protection) and rice (which is protected). Taken together, this suggests that an interventionist trade policy is not an alternative to remedying the inefficiencies that stem from inadequate rural infrastructure.

The research framework also addresses the need to identify a market that may serve as a reference (i.e. benchmark) price for traders and other participants in Tanzania. This benchmark will vary by season and commodity. For local Tanzanian maize markets, the price in Nairobi may serve as the benchmark during the Tanzanian harvest season. However, during the lean season, Nampula is the primary reference market. For rice, Bukoba is the primary market during the harvest season, while Arusha is also important. However, during the lean season, despite restrictions on formal rice imports, international markets (Vietnam and Pakistan) are the appropriate price benchmarks.

More generally, amidst the multitude of available regional and world price information, policy makers need to develop a more precise understanding of the origins of the external influences on domestic food markets. The methods and results, summarized in this brief, may be used to identify the most influential external markets. This will, in turn, lead to an improved understanding of the external sources of domestic food price volatility.

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