Cross country maize market linkages in Africa: integration and price transmission across local and global markets

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Abstract:

In order to study short run price shock propagation, we model twenty seven sub-Saharan African domestic maize markets within a Global Vector AutorRegression framework. The main purpose is to fully embed multilateral trade flows as a way to better structure local price transmission dynamics and interdependencies and get a more comprehensive picture of food price shocks propagation. We found a generally weak integration of African domestic maize markets with regional and global markets. However, even in the absence of long run integration, between-country market contagion remains significant and short run price shocks propagate rapidly. Most local markets appear to be more responsive to local than to global shocks. We also identify price shock channels linking Western African countries to South Africa through maritime trade routes.

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Abstract: In order to study short run price shock propagation, we model twenty seven sub-Saharan African domestic maize markets within a Global Vector AutorRegression framework. The main purpose is to fully embed multilateral trade flows as a way to better structure local price transmission dynamics and interdependencies and get a more comprehensive picture of food price shocks propagation. We found a generally weak integration of African domestic maize markets with regional and global markets. However, even in the absence of long run integration, between-country market contagion remains significant and short run price shocks propagate rapidly. Most local markets appear to be more responsive to local than to global shocks. We also identify price shock channels linking Western African countries to South Africa through maritime trade routes.

Keywords: Market integration, agricultural trade, Global VAR, price transmission, maize market.

1. Multilateral price transmission in SSA and the Global VAR

Since the late 2000s, the price transmission literature on food markets in developing countries has been focusing on global prices and transmission to local markets within the context of the commodity super cycle. While this was motivated by the fact that price movements from global agro-food markets can have significant food security effects (Cudjoe et al, 2010), few attempts were made to get a complete picture of domestic market interlinkages in sub-Saharan Africa (SSA) and their connection to regional trade partners.

The bulk of the established literature on agricultural prices transmission either deploys partial equilibrium macro models (Larson et all, 2013) or revolves around times series modelling of international prices pass-through to domestic markets of selected countries as well as dependencies among a few neighbors or a set of domestic markets (Abdulai, 2000; Gonzalez-Rivera and Helfand, 2001; Goodwin and Piggott, 2001; Van Campenhout 2007; Moser et all, 2009; Rapsomanikis and Mugera, 2011; Minot, 2011; Baquedano et all, 2011; Asche et all, 2012; Myers and Jayne, 2012; Baquedano and Liefert, 2014; Haile et all, 2017). A key feature of papers from this vast body of research is that they all implement some form or another of times series models such as the Error Correction Model, in their multiple or single equation settings. The number of markets that might be included in a single model is therefore limited as dimensionality problems arise when many series are added. As a result, price transmission is usually studied within small groups of markets, typically a pair of domestic markets together with an international quotation, and multilateral trade linkages are ignored.

Accounting for multilateral trade flows is relevant for sub-Saharan African markets when one wants to get a comprehensive picture of price shocks' propagation. Figure 1 illustrates the network of maize trade linkages that ties together the sub-Saharan African domestic markets analyzed in this paper. It highlights various trade patterns of connections through which domestic price shocks might propagate. It also shows the central role South Africa plays in this maize trade network. It is linked to many countries and acts as a connecting node between different groups of trade partners.

This paper sets out to provide a more partial-equilibrium approach of price transmission estimation, leveraging from a Global Vector AutoRegression (GVAR) approach applied to local African maize markets. The Global VAR allows for modelling price dynamics inside each node of the trade network and studying price shocks propagation along its linkages. The main purpose is to fully embed multilateral trade flows as a way to better structure the dynamics of price transmission and market interdependencies alongside other fundamental local supply and demand factors as well as global drivers such as oil prices and the international market.

The GVAR methodology allows one to evaluate short and long run effects of various shocks simultaneously on different markets. It solves the so-called *curse of dimensionality* problem by achieving a high degree of parsimony in the estimated models. With flexible dynamic specifications, country-specific vector error correction models are connected to multiple channels of international linkages, uncovering the size and transmission speed of price shocks emanating from neighboring countries or from the global food market.

To accommodate for many trade partners as well as different exogenous global drivers such as input costs, crude oil, or global growth, the GVAR model stacks country-specific or market-specific VAR models and connects them locally through the construction of weighted foreign variables.

To our knowledge, the GVAR methodology has so far only been applied once to the case of agro-food markets and with a focus on the main wheat exporting countries (Guttierez et al., 2015) and their sensitivity to El Nino effects (Guitterez, 2017). We set our focus on maize and African countries, most of which are not net exporters and have modest weights on the world markets.

Focusing on one of the major subsistence food crop in the continent, traded among a majority of African countries, this paper adds to the existing literature with a new understanding of local market linkages and short run price shocks vulnerability in a context of lower between-country and regional market integration. Besides, it takes the case of local domestic markets where liquidity and availability might be hampered by transaction costs, low provision of market infrastructures such as storage or rural roads, which affects the degree of price transmission and shocks absorption.

The focus on domestic food markets linkages rather than global markets is particularly relevant for food security as changes in international markets quotations are rarely fully transmitted to domestic prices. Domestic markets are prone to price events related to their own context such as production failure, droughts, trade and food security policies. These country specific shocks might in turn directly impact close trade partners. Understanding the behavior of domestic food prices is therefore important since each country might have its own market dynamics and be subjected to neighboring trade partners in specific ways, depending on their market structures, geography and trade policies.

A GVAR model enables us to derive a global view on market integration and contagion from external and internal shocks in a more dynamic fashion and less comparative static way, accounting for global inter and intra-continental trade with historical exporters. We rely on GVAR estimates and generated generalized impulse response function (GIRF) to study the effect of local and global shocks on maize prices, exchange rates, crude oil prices at the country level. We derive insights from the comparison of different country responses to local shocks, originating from various nodes of the network, and to global shocks. We are eventually able to unfold the mapping of shocks transmissions, and derive a set of full interdependencies of local markets.

We found a generally weak integration of sub-Saharan Africa domestic maize markets with regional and global markets. However, between-country market contagion remains significant and price shocks propagate regionally with a low latency when trade connection exists. Furthermore, under regular market conditions, most local price series appear to be more responsive to local neighbors than to global shocks. We also identify price shock channels linking Western African countries to South Africa through maritime trade routes.

2. Methodology

The GVAR is built on vector error correction models (VEC), i.e., VAR models with cointegrating vectors used in the estimation of the equation system to correct for common trends and long run relationships across time series. The GVAR goes several steps further than usual VECs by allowing to simultaneously study large groups of countries and accounting for trade patterns and global common exogenous variables, such as global food markets, currencies, or world financial markets. Introduced by Pesaran et al., 2004, it was updated and extended with a stronger theoretical background by Dees et al., 2007.

The GVAR is built in two steps. First, individual time series of each country or entity are modelled as a function of domestic and foreign variables in a vector autoregression with exogenous variables (VARX) fashion. Foreign variables are weighted averages of trade partner's domestic market prices. Weights are chosen based on total maize trade flows between countries[1]. The construction of foreign variables and the trade flows matrix are what disentangles and renders explicit national and regional price interdependencies arising from trade networks. Cointegration vectors are computed when cointegration is detected. Every domestic maize price series can also be affected by global variables. We consider global export maize markets and crude oil price (as a strong predictor of non-labor production costs).

Once estimated, country models are stacked to form the GVAR model wherein global variables are exogenous. Global variables are endogenous in a so called dominant unit model (Chudik and Pesaran, 2013). Generalized Impulse Response Functions (GIRFs) are employed to analyze the results and illustrate sensitivity to external and internal shocks. Let us now write down in details the equations to be estimated.

[1]Trade flows are by nature endogenous to prices equations but the product of the weighted averages, the foreign variables, are tested for weak exogeneity.

For country i, consider the VARX(2,2) structure:

$$x_{it} = a_{i0} + a_{i1}t + \Phi_{i1}x_{i,t-1} + \Phi_{i2}x_{i,t-2} + \Lambda_{i0}x_{it}^{*} + \Lambda_{i1}x_{i,t-1}^{*} + \Lambda_{i2}x_{i,t-2}^{*} + \Psi_{i0}\omega_t + \Psi_{i1}\omega_{t-1} + \Psi_{i2}\omega_{t-2} + u_{it}, \quad (1)$$

for i = 0,1,...,N, with x_{it} , a $k_i \times 1$ vector of domestic variables. Φ_{it} contains the associated temporal coefficients. x_{it}^{*} is a $k_{it}^{*} \times 1$ vector of foreign variables with their vector of coefficients Λ_{it}. They represent the influence of trade partners markets on a given national market. It is computed as:

$$x_{it}^{*} = \Sigma_{j=0}^{N} w_{ij}x_{jt} ,$$

with $w_{ii} = 0$ and w_{ij}, for $j = 0,1,\dots,N$ are a set of bilateral trade flows based weights between country i and its partners such that $\Sigma_{j=0}^{N} w_{ij} = 1$. The international market is susceptible to pervasively influence all country models. Hence, ω_t contains global variables that are weakly exogenous to all countries but endogenous in a global market model, considered dominant in the sense of Chudik and Pesaran (2013). Although these variables are common to all models, they affect each domestic market i to a different degree, as specified by Ψ_{it}, the vector of associated autoregressive coefficients. a_{i0} is a vector of $k_i \times 1$ constant intercepts and a_{i1} a $k_i \times 1$ vector of coefficients of deterministic time trends.

The error correction form of the VARX(2,2) specification[1] may be written as

$$\Delta x_{it} = c_{i0} - \alpha_i\beta_i'\left[z_{i,t-1} - \gamma_i(t-1)\right] + \Lambda_{i0}\Delta x_{it}^{*} + \Gamma_{\mathrm{i}}\Delta Z_{i,t-1} + u_{it} \quad (2)$$

where $z_{it} = (x_{it}', x_{it}'^{*})'$, α_i is a $k_i \times r_i$ matrix of adjustments parameters determining the speed of adjustment towards the long-run equilibrium and β_i is a $(k_i + k_i^{*}) \times r_i$ matrix of rank r_i containing the long-run relationships (cointegrating vectors) between local markets. Λ_i and Γ_{i} contain respectively the short-run responses to international and domestic variations. The rank of $\alpha\beta'$ allows one to determine the presence of cointegration. When $rank(\alpha\beta') = 0$, variables are not cointegrated, and the model becomes equivalent to a

[1] For the presentation of the estimation of country models, we will consider global variables implicitly included in the set of foreign variables.

VARX in first differences. By partitioning β_i as $\beta_i = (\beta'_{ix},\beta'_{ix^*})$' conformable to z_{it}, the error correction can be written in the form of

$$\beta_i'[z_{it} - \gamma_i t] = \beta_{ix}' x_{it} + \beta_{ix^*} x_{it}^* - (\beta_i' \gamma_i)t$$

which allows for the possibility of cointegration both within the set of domestic variables, x_{it}, and between domestic variables and foreign or global variables, x_{it}^* for $i \neq j$.

For estimation and upon appropriate testing, foreign variables, x_{it}^*, are treated as I(1) weakly exogenous with respect to the long-run parameters of VARX models. This implies that, when cointegration is detected, the error correction terms of individual country VECMs do not enter in the marginal model of x_{it}^*. This assumption allows for each country model to be consistently estimated separately, conditional on x_{it}^*. Using reduced-rank regression, we can therefore include exogenous regressors and allow for cointegration both within x_{it} and between x_{it} and x_{it}^*. By doing so, the number of cointegrating relations, r_i, the speed of adjustment coefficients, α_i, and the cointegrating vectors β_i are obtained for each country model.

Conditional on a given estimate of β, the remaining parameters of the VARX model are consistently estimated by OLS regressions of the following equation:

$$\Delta x_{it} = c_{i0} + \delta_i ECM_{i,t-i} + \Lambda_{i0} \Delta x_{it}^* + \Gamma_i \Delta z_{i,t-1} + u_{it}$$

where $ECM_{i,t-i}$ are the terms of the r_i cointegrating relations of the i^{th} country model.

The lag orders of domestic and foreign variables, p_i and q_i respectively, are chosen according to the Akaike Information Criterion (AIC). The lag order of the GVAR, denoted by p, is the maximum of p_i or q_i across all countries. The corresponding cointegrating VARX models are then estimated and the rank of their cointegrating space is determined using the error-correction forms of the individual country equations (eq. 2) with Johansen's trace and maximal eigenvalue statistics for models with weakly exogenous I(1) regressors (Pesaran et al., 2000). To solve for the GVAR, local and foreign variables are stacked in $z_{it} = (x_{it}, x_{it}^*)'$ and equation 1 is rewritten as:

$$\begin{aligned} G_{io} z_{it} = a_{i0} + a_{i1} t + G_{i1} z_{i,t-1} + G_{i2} z_{i,t-2} \\ + \Psi_{i0} \omega_t + \Psi_{i1} \omega_{t-1} + \Psi_{i2} \omega_{t-2} + u_{it} \end{aligned} \qquad (3)$$

where $G_{io} = (I_{ki} - \Lambda_{\mathrm{i0}}), G_{ij} = (\Psi_{ij}, \Lambda_{\mathrm{ij}})$, for $j = 1,2$. We can then use all link vectors from matrix W_i, defined by the trade weights w_{ij}, to obtain the identity:

$$z_{it} = W_i x_t, \quad \forall i = 0,1,\dots,N \tag{4}$$

where $x_t = (x'_{0t}, x'_{1t}, \dots x'_{Nt})$ is the $k \times 1$ vector which collects all endogenous variables of the system, and W_i is a $(k_i + k_i^*) \times k$ matrix containing weights that will account for trade linkages. Trade based weights are computed as $w_{ij} = X_{ij} + M_{ij}$, were X_{ij} and M_{ij} are respectively the total the exports and imports volumes from i to j over the sample period[1]. The W_i matrix allows each country model to be written in terms of the global variable vector, x_t. Thus, it is the fundamental device through which markets are related to one another in the GVAR model.

Country models can be estimated separately, but a single global set of matrices is required for simulation and forecasting purposes as well as analyzing the cross-country residuals covariance. Therefore, all country-VARX equations modelled with (3) are connected to each other through identity (4), which yields a single country model of the form:

$$\begin{aligned} G_{i0} W_i x_t = a_{i0} + a_{i1} t + G_{i1} W_i X_{t-1} + G_{i2} W_i X_{t-2} \\ + \Psi_{i0}\omega_t + \Psi_{i1}\omega_{t-1} + \Psi_{i2}\omega_{t-2} + u_{it} \end{aligned} \tag{5}$$

for $i = 0,1,\dots,N$, and $G_{ij} W_i$ has dimensions $k_i \times k$.

Finally, by stacking each country-specific model (5), we derive the Global VAR(2) model for all endogenous variables in the system, x_t:

$$\begin{aligned} G_0 x_t = a_0 + a_1 t + G_1 x_{t-1} + G_2 x_{t-2} \\ + \Psi_{i0}\omega_t + \Psi_{i1}\omega_{t-1} + \Psi_{i2}\omega_{t-2} + u_t \end{aligned} \tag{6}$$

Defining the $(k + m_\omega) \times 1$ vector $y_t = (x_t', \ \omega_t')$ combining k domestic and foreign variables with m_ω global variables, we write (6) as

$$H_0 y_t = h_0 + h_1 t + H_1 y_{t-1} + H_2 x_{t-2} + \zeta_t,$$

Where the h_j matrices collect the intercept and trend parameters of the dominant unit model (μ_0, μ_1) together with those of country specific models and the H matrices contain

[1] Time varying trade flows would give less weight to periods with no trade between two partners even though prices might be connected by the possibility of trade (Barret and Li, 2002), thereby underestimating transmission.

the temporal coefficients of the dominant unit and country models (Φ_j, G_j, Ψ_j). The innovations of the dominant unit system, η_t, are assumed uncorrelated with country specific models residuals, u_t.

$$H_0 = \begin{bmatrix} G_0 & -\Psi_0 \\ 0_{m_\omega \times k} & I_{m_\omega} \end{bmatrix},\ h_0 = \begin{bmatrix} a_0 \\ \mu_0 \end{bmatrix}, h_0 = \begin{bmatrix} a_1 \\ \mu_1 \end{bmatrix},$$

$$H_j = \begin{bmatrix} G_j & \Psi_j \\ \Lambda_j W_j & \Phi_j \end{bmatrix}, j = 1,2;\ \zeta_t = \begin{bmatrix} u_t \\ \eta_t \end{bmatrix}.$$

To finally obtain the GVAR in its reduced form, we invert the H_0 matrix:

$$y_t = c_0 + c_1 t + C_1 y_{t-1} + C_2 y_{t-2} + H_0^{-1} \zeta_t \tag{7}$$

where $c_j = H_0^{-1} h_j,\ C_{j+1} = H_0^{-1} H_{j+1},\ \ j = 0,1;$.

This GVAR model allows for interdependence through three channels: (i) the contemporaneous correlation of local market variables, x_{it}, with their foreign counterparts, x_{it}^*, and their lagged values; (ii) the dependence of local market variables, x_{it}, on global variables, d_t, such as oil prices and international markets and their related lagged values; and (iii) the contemporaneous dependence of shocks in country *i* on the shocks in country *j*, as described by the cross-country covariances of residuals, $\Sigma_{ij} = Cov(u_{it}, u_{ij}')'$, for $i \neq j$.

Impulse response functions measure the time profile of the effect of shocks at a given point in time on the expected forward values of variables in a dynamical system. More specifically, the impulse response function gives the *j*th period response when the system is shocked by a one-standard-deviation shock. Impulse responses of shocks to specific variables considered for the GVAR model are the generalized impulse response functions (GIRFs), introduced in Koop et al. (1996) and adapted to VAR models by Pesaran et al., 2000. Unlike usual impulse response analysis, this approach does not require orthogonalization of shocks and is invariant to the ordering of variables in the VAR[1]. This is useful here as there is no a priori ordering of countries that would lead to a clear identification of orthogonal shocks.

[1] While GIRFs are invariant to the ordering of the variables, one needs to be cautious when interpreting the effect of shocks using GIRFs, as they allow for correlation of error terms and given that error terms are not orthogonal.

3. Data and empirical model

We combine two United Nations food price datasets - World Food Program (WFP) and Food and Agriculture Organization (FAO) - to obtain a monthly maize price series coverage for 27 SSA countries between January 2007 and December 2016. The WFP works with the national agriculture (or other) ministry to obtain the data from their market information system, but if the existing system does not cover WFP's information needs, the organization sets up its own local data collection system. The FAO gathers price series solely from official national sources such as the ministry of agriculture and bureaus of statistics. We choose wholesale over retail price series whenever the series length makes it possible and we use median prices when multiple series are available. Occasional data gaps were filled with a compounded growth rate.

All prices are converted in US dollars with nominal exchange rates extracted from the International Monetary Fund dataset. The consumer price index is used in the equation systems to control for inflation and linkages with other goods. The spot crude oil price comes from the World Bank pink sheet. The US corn export spot prices[1] are from the FAO price monitoring system.

The trade data is obtained from the CEPII/BACI dataset. BACI is constructed using an original procedure that reconciles declarations of exporters and importers provided by the United Nations Statistical Division (COMTRADE database). This harmonization procedure enables to extend considerably the number of countries for which trade data are available, as compared to the original dataset. First, as import values are reported CIF (cost, insurance and freight) while exports are reported FOB (free on board), CIF costs are estimated and removed from imports values to compute FOB import values. Second, the reliability of country reporting is assessed based on the reporting distances among partners. These reporting qualities are used by the CEPII as weights in the reconciliation of each bilateral trade flow twice reported.

The country-specific domestic, x_{it}, and foreign, x_{it}^*, vectors for countries *i=1,…, N* are defined as: $x_{it} = \left(p_{it}^m, p_{it}^{cpi}, er_{it}\right)'$ and $x_{it}^* = (p_{it}^{m*}, p_t^{oil}, p_t^{int})$. Where p_{it}^m is the nominal

[1] Among the major international markets maize quotations, US corn FOB prices exhibit the highest average correlation with our sample of African prices and were therefore retained in the model.

local maize price in US dollars and p_{it}^{cpi}, the local consumer price index, accounts for general inflation movements. er_{it} is the local currency exchange rate with the US dollar. p_t^{oil}, p_t^{int} are the spot oil price and international maize prices in US dollars and both are considered as global variables from the dominant unit model. p_{it}^{m*} is the country-specific weighted average of maize prices in trade partners' own markets. It is computed with trade weights based on total maize trade flows over the period 2007-2015, and defined as follows: $p_{it}^{m*} = \Sigma_{j=0}^{N} w_{ij} p_{it}^{m}$. The weight matrix is constructed with the CEPI adjusted trade flows among the group of countries included in the GVAR and averaged over time, as explained above. All series are log transformed.

4 Specification tests and model estimates

We assess the presence of unit roots with Augmented Dickey–Fuller (ADF) tests as well as unit root t-statistics based on weighted symmetric estimation (WS) of ADF regressions that exploit the time reversibility of stationary autoregressive processes for better performance. In most cases, for endogenous and exogenous variables, the null hypothesis of unit root cannot be rejected at the 5% significance level (Appendix Table 1) and we consider variables to be I(1). In the presence of cointegration, this allows us to distinguish between short-run and long-run relations and interpret the long-run relations as cointegrating.

The number of cointegration relationships is selected based on maximal eigen value statistics, as laid out in section 2. Models are expressed in their VECMX form when required and, depending on the results of the likelihood ratio test suggested by Pesaran, Shin and Smith (2000), the error correction term is allowed to trend. Only 60% of country models were found to have at least one cointegration vector which can stem from integration within the domestic variables or with trade partners'. This denotes a generally weak integration of domestic maize markets with regional and global markets, in line with findings from the literature such as those of Minot (2011) and Baquedano and Liefert (2014). However, on average, price levels are correlated across countries. And, albeit low, the correlation across price returns suggest that domestic prices are partly driven by something else than a common trend and warrants further analysis (Table 2). Uncorrelated residuals show that the VECMX are effective in accounting for common factors driving domestic prices.

A key assumption for the GVAR is the small country hypothesis, under which no single country should be able to impact global and foreign variables. For countries where cointegration has not been ruled out, we test for weak exogeneity by using F-test to assess the joint significance of the error correction terms in the marginal model of weakly exogenous variables. Weak exogeneity of foreign and global variables could not be rejected as all cases were found to be non-significant (Appendix table 2).

Contemporaneous foreign variables coefficients can be interpreted as the sensitivity of domestic maize prices to price shocks in trade partners' markets. These elasticities represent the degree of short run price transmission and market integration between domestic maize markets and foreign markets. For instance, in Senegal and Gambia, a 10% increase in foreign prices respectively translates into a 4.9% and 5% increase of domestic prices within the same month (Table *3*).

Elasticities are generally positive and most coefficients lie within the 0.25-0.6 band, denoting a rapid and significant short run price shock transmission from neighboring trade partners even in the absence of long run cointegrating relationship.

To the exception of Ghana and Nigeria, which have strong internal production markets, Western African coastal countries like Benin, Togo and Ivory Coast have high elasticities and so does Senegal and Cameroon to a lower extent. Those coastal countries rely on intra-continental imports for maize consumption, and act as transiting channels for their more landlocked neighbors' imports. On average, we do not find significantly different coefficients for non-land-locked countries.

5. Generalized impulse response analysis

By means of GIRFs, we analyze and compare the dynamic response of local maize prices over a 12 months time horizon after different shocks. Each graph presents the median response in a 90 percent confidence interval obtained from 5000 bootstrap replications.

First, an upward shock of one standard deviation of domestic prices is introduced to the system in Tanzania, a prominent maize producer in the East African Community. Second, we discuss a one standard deviation positive increase of South African prices, which are central to the continent's trade network. Each panel of GIRFs is accompanied by information on the country's relative importance of in the trade structure of its trade partners. This relative first degree connection is the weight, w_{ij}, of country i, through which the shock enters the system, in the foreign prices composition of its direct trade partners, $j = 0,1, \dots, N$.

5.1. A domestic price shock in Tanzania

Full transmission of a one standard error shock in Tanzania to neighboring countries generally takes three months (Figure 2**: Panel of local prices generalized impulse responses to one standard error positive shock to prices in Tanzania**). This shock amounts to a 2.5% increase in domestic Tanzanian prices and translates into between 0.5% and 1% median reaction among Burundi, Rwanda, Zambia and Malawi. In Kenya, a maize export market for Tanzania, the reaction takes up to four month to reach its maximum intensity. The rest of Tanzania's direct trade partners do not exhibit a significant reaction in their domestic prices following the shock. Burundi trades most of its maize with Uganda and Rwanda but its 10% relative connection to Tanzania over the sample period was sufficient to observe a reaction in its domestic market following the Tanzanian shock. Mozambique shares a similar connection with Tanzania but has tighter maize trade links with South Africa, which might have rendered it more resilient to developments in Tanzania. South Africa shows no reaction to turmoil in Tanzanian markets.

5.2. A domestic price shock in South Africa

Compared to the Tanzanian scenario, a one standard deviation shock in South Africa's domestic markets affects more countries (Figure 4). It generates a well-defined reaction in Kenya, Uganda, Zambia and Swaziland. Impulse responses in Rwanda, Cameroon and Congo (DRC) are less distinct but still significant. The 3% price increase is not the sufficient to observe a median response significantly different from zero in Tanzania, Malawi and Mozambique. However, the response is particularly visible in coastal Western African countries connected by maritime routes such as Senegal, Gambia, Togo, Benin and Ivory Coast. The response is however much weaker for Nigeria and Ghana. The shock also travels to landlocked importers via coastal neighbors channeling trade flows to countries such as Mali and Chad and Niger. Interestingly, even though Burkina Faso does not trade a lot with South Africa and is generally an exporter of maize, the effect of a South African shock still penetrates its market, albeit with a one or two months delay.

While Senegal is sensitive to a South African shocks, the contrary does not hold has South African prices do not react to a shock applied to the Senegal sub-system (Figure 3).

5.3 International markets and oil prices shocks

A one standard deviation shock to US corn export prices amounts to a 2% increase in this major export market. Compared with local equivalents, a price shock from the international market takes more time to be fully transmitted. However, most local African markets seem less significantly and less predictably affected by international price shocks. Only Kenya and South Africa respond to international price shocks and in a coherent fashion, owing to their stronger integration with global markets. The rest of our sample does not exhibit a median response significantly different from zero.

Crude oil is one of the main drivers of worldwide inflation and agricultural non-labor production costs. Moreover, currency markets' volatility can underlie periods of global macroeconomic risks, volatility, and recession. Local currencies' behavior can reflect local macroeconomic shocks or changes in macroeconomic policies and governance. We compute impulse responses of local maize markets of a global shock on the US dollar and on crude oil, made available in a data appendix. However, one-standard deviation positive shock on crude oil prices and a global shock on local exchange rates with the dollar does not generate significant price responses in most local markets.[1] This can be due to the fact that such shocks are more rapidly and significantly transmitted to international prices and only indirectly to local markets, through global ones. Most maize production systems in Africa are rather input-light and of low-intensive use of chemical inputs. Hence a lower sensitivity to oil and dollar variations. A small reaction to the global oil shock, between 0.5 and 1%, was however picked up in countries within the West African block such as Senegal, Mali, Niger, Burkina Faso, and Ghana, as well as in Ethiopia in Eastern Africa.

6. Concluding remarks

This paper presents an application of the Global Vector Autoregressive model to twenty seven sub-Saharan African maize markets. Vector error correction models with weakly exogenous variables are estimated and connected. The main purpose is to fully embed

[1] Not included in this manuscript but available in a data appendix.

multilateral trade flows as a way to better structure local price transmission dynamics and interdependencies. This modelling framework applied to maize price transmission analysis builds up an approach which enables to clarify regional and local patterns with a focus on local markets dynamics and get a more comprehensive picture of food price shocks propagation.

We found a generally weak integration of domestic maize markets with regional and global markets. However, even in the absence of long run integration, between-country market contagion remains significant and short run price shocks propagate rapidly, as illustrated by generalized impulse response functions. Furthermore, most local markets appear to be significantly more responsive to shocks affecting regional trade partners than to global shocks from international markets.

Western African countries were found to be affected by South African price movements, linked by maritime routes. The opposite was not observed as Eastern Africa in general is seldom affected by Western African market developments.

Our results also highlight that, when effectively transmitted to trade partners, shocks usually generate long lasting deviation of prices from their equilibrium position. Such hysteresis renders traditional agricultural policy tools, such as emergency stocks and trade policy, inefficient in managing prices in the long run. It calls for the root causes to be addressed internally by making production systems and marketing channels more resilient.

A distinguishable feature of the network's reaction to shocks simulated in this paper is that propagation does not go further than one degree of connections. We did not identify countries affected by turmoil's originating outside of their first degree trade connections. However, we simulated one standard deviation shocks which amplitudes are relatively common. This might not be the case with extreme events and nonlinearities should be introduced to model reactions to exceptional price movements (see Abidoye, 2014 for South Africa).

Even though bounded by direct trade connections, significant short term price transmission is especially a concern for land-locked countries for whom imports are more expensive and whose food consumption relies on local production and therefore remains vulnerable to tight stocks as well as poor storage infrastructures and policies. From a policy perspective, while long run price transmission is a desirable market feature, short term shocks require some level of mitigation. Sensitivity to short term price shocks underlines the need and usefulness of strengthening the set of mitigation mechanisms available to national governments. Regional policy frameworks could help further investments in market infrastructures to lower between-country and regional transaction costs of grains trade while enabling countries to access cheaper maize prices from their neighbors when facing a local production shock. But we showed that price turmoil might be exported to trade partners' domestic markets either because domestic tools where not sufficient or because trade policy was used to pass on part of the burden. Hence regional dialogue, together with investment in domestic markets, is essential to successfully prevent adverse effects of internal disruptions.

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Tables

Table 1: VARX order and number of Cointegrating Relationships

	VARX*(p_i,q_i)		# Cointegrating relations		VARX*(p_i,q_i)		# Cointegrating relations
	p_i	q_i			p_i	q_i	
Burundi	5	1	1	Malawi	3	1	1
Benin	1	1	0	Niger	2	1	1
Burkina Faso	2	1	1	Nigeria	2	1	0
Central Africa	1	1	2	Rwanda	3	1	1
Ivory Coast	2	1	1	Senegal	1	2	0
Cameroon	1	2	0	Somalia	3	1	0
Congo	5	3	1	Swaziland	2	1	1
Cape Verde	2	1	0	Chad	1	1	0
Ethiopia	4	2	0	Togo	4	1	1
Ghana	5	3	1	Tanzania	2	2	0
Gambia	1	3	1	Uganda	3	1	0
Kenya	2	1	1	S. Africa	3	1	1
Mali	1	1	1	Zambia	2	1	0
Mozambique	5	1	1				

Note: The rank of the cointegrating orders for each country is computed using Johansen's trace and maximum likelihood statistics at the 95% critical value level. The lag for domestic endogenous variables, p_i, is allowed to differ from the lag of the exogenous foreign vectors, q_i, and the selection is conducted with the AIC criteria

Table 2: Domestic prices average Pairwise Cross-Section Correlations

	Levels	First Differences	VECMX* Residuals		Levels	First Differences	VECMX* Residuals
Burundi	0.135	-0.010	-0.019	Malawi	0.211	0.000	-0.001
Benin	0.279	0.099	0.017	Niger	0.354	0.155	-0.001
Burkina Faso	0.331	0.126	0.007	Nigeria	0.337	0.080	0.022
Centr.Africa	0.210	0.040	0.025	Rwanda	0.353	0.056	0.002
Ivory Coast	0.228	0.088	0.045	Senegal	0.293	0.129	0.034
Cameroon	0.330	0.085	0.023	Somalia	0.251	0.091	0.033
Congo	0.102	0.012	-0.014	Swaziland	0.162	0.072	0.033
Cape Verde	0.077	0.126	0.043	Chad	0.284	0.102	0.039
Ethiopia	0.330	0.121	0.044	Togo	0.269	0.069	0.004
Ghana	0.223	0.066	0.014	Tanzania	0.343	0.070	0.004
Gambia	-0.069	-0.002	-0.033	Uganda	0.390	0.060	-0.003
Kenya	0.384	0.068	-0.019	S. Africa	0.163	0.072	-0.024
Mali	0.307	0.124	-0.003	Zambia	0.079	0.009	-0.046
Mozambique	0.231	-0.033	-0.039		0.211	0.000	-0.001

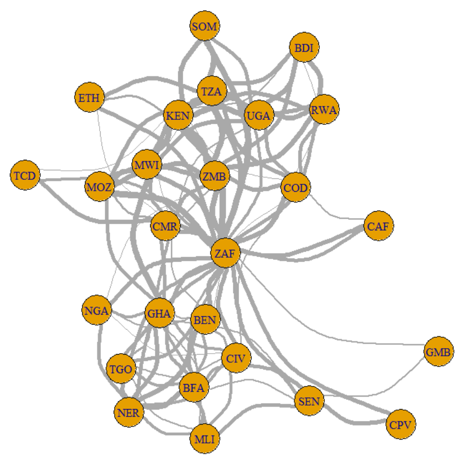
Table 3: Contemporaneous Effects of Foreign Prices on Domestic Counterparts

	Λ_{i0}		Λ_{i0}		Λ_{i0}		Λ_{i0}		Λ_{i0}
Burundi	0.087 (0.16)	Congo	0.397 (0.177)	Mali	0.681 (0.113)	Senegal	0.489 (0.124)	Uganda	0.734 (0.272)
Benin	0.718 (0.238)	Cape V.	0.283 (0.141)	Mozambique	-0.045 (0.153)	Somalia	0.065 (0.196)	S. Africa	0.108 (0.142)
Burkina Faso	0.616 (0.178)	Ethiopia	0.026 (0.151)	Malawi	0.348 (0.293)	Swaziland	0.275 (0.104)	Zambia	0.618 (0.167)
Centr. Africa	0.534 (0.269)	Ghana	-0.058 (0.103)	Niger	0.367 (0.088)	Chad	0.51 (0.207)		
Ivory Coast	0.536 (0.249)	Gambia	0.504 (0.205)	Nigeria	0.375 (0.148)	Togo	1.047 (0.322)		
Cameroon	0.258 (0.112)	Kenya	0.277 (0.169)	Rwanda	0.355 (0.209)	Tanzania	0.457 (0.203)		

Note: robust standard errors in parenthesis, computed with White's heteroskedasticity-consistent variance estimator.

Figures

Figure 1: Maize trade network in SSA



Note: Force directed layout of maize trade network. Width of links based on log of total 2005-2014 trade flows from the CEPI/BACI data set. Countries which share more and stronger connections are closer to each other.

Figure 2: Panel of local prices generalized impulse responses to one standard error positive shock to prices in Tanzania

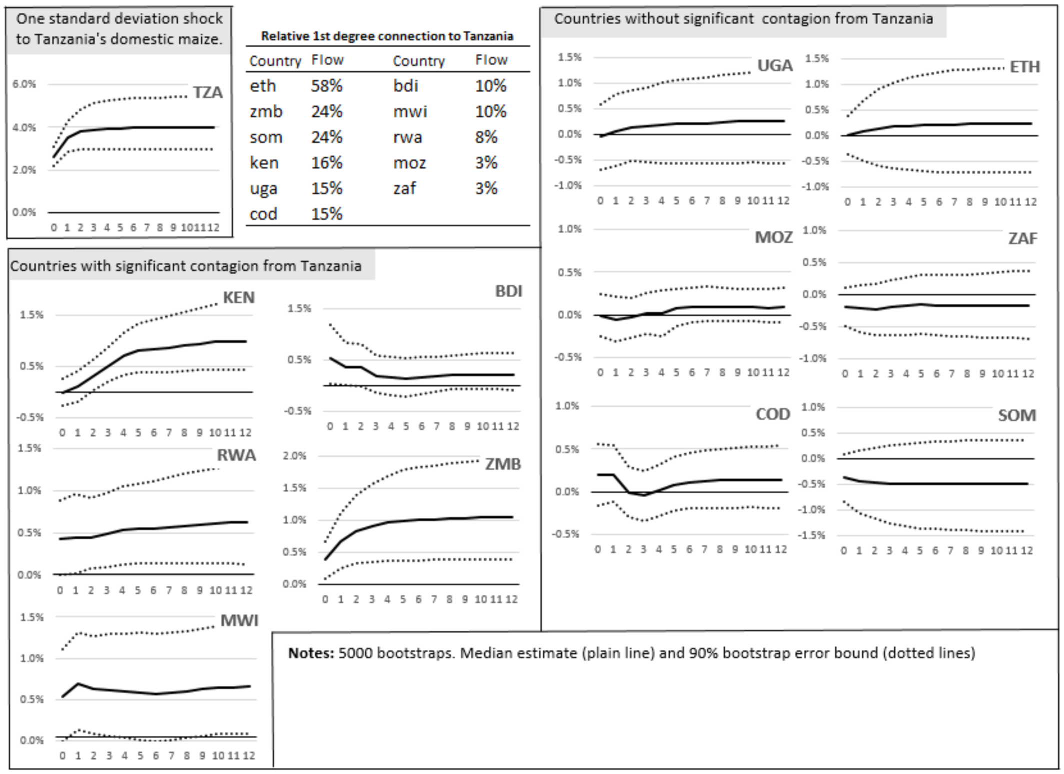


Figure 3: Panel local prices generalized impulse responses to one standard error positive shock to prices in Senegal

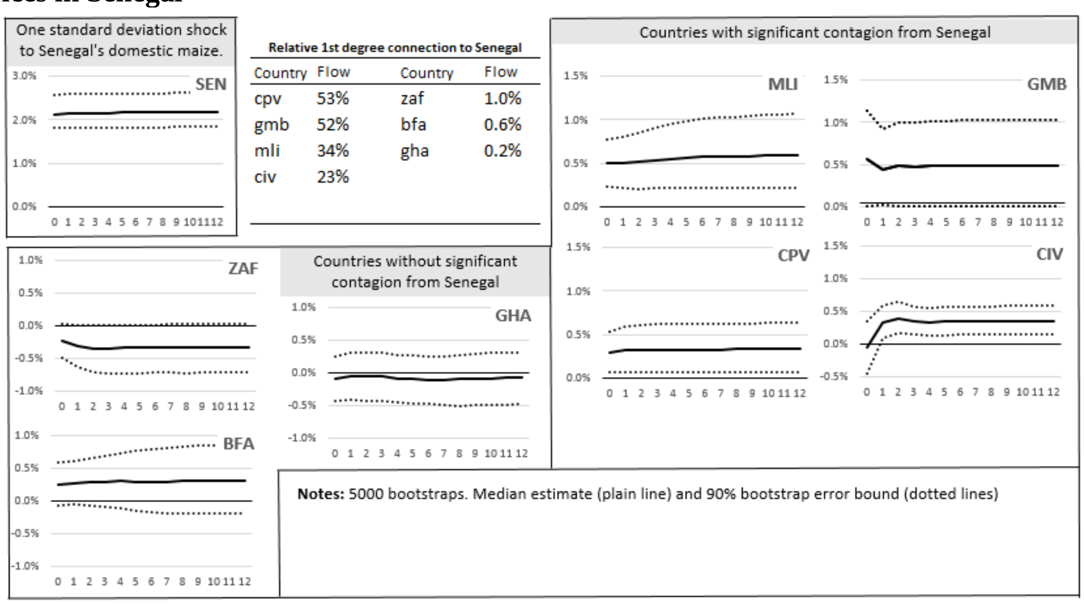


Figure 4: Panel of domestic prices generalized impulse responses to one standard error positive shock to South African prices

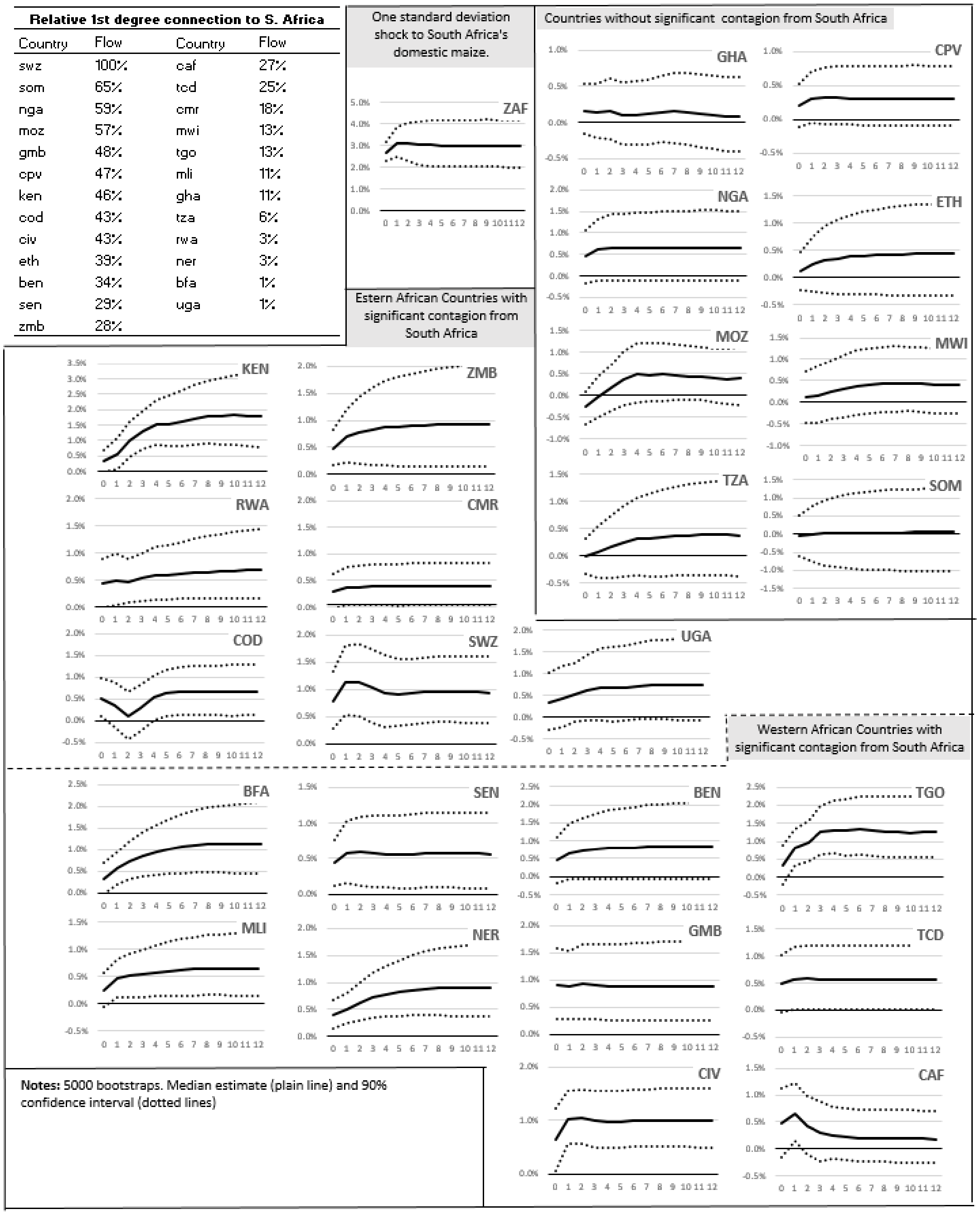


Figure 5: Domestic prices generalized impulse responses to one standard error positive shock to international prices