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

Guillaume Pierre[1,2], Jonathan Kaminski[1]

[1] Food and Agriculture Organization of the United Nations.
[2] Department of Economics and Social Sciences, Sapienza University of Rome.

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Abstract: 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 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 significantly more responsive to local than to global shocks.

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

1 Multilateral price transmission in SSA and the Gobal VAR

Since the late 2000s, the literature on food markets behavior in developing countries has had a strong focus on global prices and transmission to local markets within the context of the commodity super cycle. While this has been 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 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 the pass-through between international prices and the domestic markets of selected countries as well as among a few neighbors or a set of domestic markets (Gonzalez-Rivera and Helfand, 2001; Goodwin and Piggott, 2001; Van Campenhout 2007; Moser et all, 2009; Rapsomanikis and Mugera, 2011; Minot, 2011; Mafimisebi, 2012; Myers and Jayne, 2012; Baquedano and Liefert, 2014). A key feature of papers from this large 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 quickly arise when many series are added. As a result, price transmission is usually studied among 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 domestic markets of sub-Saharan African countries analyzed in this paper. It highlights various trade patterns through which domestic price shocks might propagate. It also shows the central role South Africa has in the 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 and global drivers such as oil prices and exchange rates.

The GVAR methodology allows one to evaluate short-term and long-term effects of various shocks simultaneously on different markets and in a partial-equilibrium fashion since all market interdependencies are explicitly modelled. The GVAR solves the so-called curse of dimensionality problem by achieving a high degree of parsimony in the estimated models. It allows for flexible dynamic specification through which 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 the global food market or from neighboring countries.

For instance, it is possible to look at the effect of local domestic, local foreign and global foreign shocks which might be endogenous or exogenous to a specific market and country. While standard VAR models would be used to study price transmissions between different markets and investigate the effect of foreign shocks, they could not be connected to many trade partners as well as exogenous global drivers such as input costs, crude oil, or global growth. The GVAR model allows for stacking country-specific or market-specific VAR models and connecting them locally through the construction of weighted foreign variables, complemented by global variables.

To our knowledge, the GVAR methodology has only been applied once to the case of food markets and with a focus on the main wheat exporting countries (Guttierez et al. 2015).[1] In this paper, we focus on maize and African countries, most of which are not net exporters and little players on the world markets. Hence, the assumption of no-feedback effect from local to global markets, which is underlying in GVAR models, is more likely not to be rejected.

Focusing on one of the major subsistence food crop in the continent and its contribution to food security in non-traditional exporting 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. Maize is among the few commodities traded among a majority of African countries.

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 and derive insights from the comparison of different country responses depending on where the local shock is originating or on the type of global shock. 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 domestic maize markets with regional and global markets. However, between-country market contagion remains significant and price shocks propagate regionally with a low latency. Furthermore, most local markets appear to be significantly more responsive to local than to global shocks on other maize markets. We also identify price shock channels going through maritime routes that have been ignored by the literature thus far.

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 across time

[1] While they didn't focus on developing countries, their implementation of the model is relevant to our discussion. They proposed a Global Wheat Market Model (GLOWMM) to study the impacts of the main factors behind wheat export price dynamics of the main exporting countries, USA, Argentina, Australia, Canada, Russia and EU.

series. The GVAR goes several steps further than usual VECs, by allowing large groups of countries to be studied at the same time and accounting for trade patterns to relate them to global common variables, assumed exogenous, such as global growth and volatility, currencies, or world financial markets. Introduced by Pesaran et al., 2004, it was updated and extended with a stronger theoretical background and the possibility of structural impulse response 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 contemporaneous and lagged domestic variables and lagged foreign (but local) variables in a VARX fashion. In our case, the foreign variables are weighted averages of trade partner's markets price series. Additional foreign variables can also be used to reflect non-price variables' exogenous influence on local markets. The weights are chosen based on total maize trade level 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 national maize price series can also be affected by global variables. We consider global export maize and wheat markets, crude oil price (as a strong predictor of non-labor production costs), and exchange rates.

Once estimated the country models are stacked to form the GVAR model and wherein global variables are exogenous. Global variables are also interacting with one another endogenously. 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.

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

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

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 $\Sigma_{j=0}^{N} w_{ij} = 1$. d_t contains the global variables that are weakly exogenous to all countries but endogenous in the global markets' model, considered dominant in the sense of Chudik and Pesaran (2013). Although these variables are common to all models, they affect each domestic market 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 the deterministic time trends.

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

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

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

[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. Another approach would have been to estimate the weighting matrix aside the GVAR parameter estimates, as suggested by Gross, 2013.

[2] As of now we will consider that the 2 global variables are implicitly included in the set of foreign specific variables of all country-level equations.

$\alpha\beta'$ allows one to determine the presence of cointegration. When $rank(\alpha\beta') = 0$, variables are not cointegrated, and the model becomes equivalent to a 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, the foreign variables, x_{it}^*, are treated as I(1) weakly exogenous with respect to the long-run parameters of the VARX model. This implies that, when cointegration is detected, the error correction terms of the 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, 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, the local and foreign variables are stacked in $z_{it} = (x_{it}, x_{it}^*)'$ and equation 1 is rewritten as:

$$A_i z_{it} = a_{i0} + a_{i1} t + A_{i1} z_{i,t-1} + A_{i2} z_{i,t-2} + u_{it} \quad (3)$$

where $A_i = (I_{ki} - \Lambda_{\text{i0}}), A_{i1} = (\Psi_{i1}, \Lambda_{\text{i1}}), A_{i2} = (\Psi_{i2}, \Lambda_{\text{i2}})$. We can then use all the link vectors from matrix W_i, defined by the trade weights w_{ij}, to obtain the identity:

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

where $x_t = (x'_{0t}, x'_{1t}, \dots x'_{Nt})$ is the $k \times 1$ vector which collects all the 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} is the total exports volume from i to j and M_{ij} the imports volume 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 for simulation and forecasting purposes and to analyze the cross-country residuals covariance, it is necessary to have one single global set of matrices, the GVAR. 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:

$$A_{i0} W_i x_t = a_{i0} + a_{i1} t + A_{i1} W_i X_{t-1} + A_{i2} W_i X_{t-2} + u_{it} \quad (5)$$

for i = 0,1,...,N, and $A_i W_i$ has dimensions $k_i \times k$.

[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.

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

$$G_0 x_t = a_0 + a_1 t + G_1 x_{t-1} + G_2 x_{t-2} + u_t \quad (6)$$

The G matrix has dimensions $k \times k$ and can be inverted if non-singular. By inverting the G matrix we obtain the Global VAR in its reduced form:

$$x_t = b_0 + b_1 t + F_1 x_{t-1} + F_2 x_{t-2} + \epsilon_t \quad (7)$$

where $F_1 = G_0^{-1} G_1$, $F_2 = G_0^{-1} G_2$, $b_0 = G_0^{-1} a_0$, $b_1 = G_0^{-1} a_1$ and $\epsilon_t = G_0^{-1} u_t$.

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 the 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 traditional 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 clear a priori ordering of countries that would lead to a clear identification of orthogonal shocks.

3 Data and empirical model

We combine the WFP/VAM and FAO/FPMA price datasets to obtain a monthly maize price series coverage for 27 SSA countries between January 2007 and December 2014 (Table 1). 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. 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 length of the series makes it possible and we use the median price when multiple markets are available. Occasional gaps in series were filled with a compounded growth rate.

All prices are converted in US dollars with nominal local exchange rates extracted from the IMF/IFS dataset. The consumer price index is used in the equation to control for inflation. The spot crude oil price comes from the World Bank pink sheet. The US corn and wheat export spot prices are from FAO/FPMA and the dollar index is constructed on a basket of major currencies' exchange rate with the US dollar.

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

[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.

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 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[1] in US dollars and both are considered as global variables from the global set of equations. 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 the total maize trade flows over the period 2007-2015, and defined as follows: $p_{it}^{m*} = \Sigma_{\mathrm{j=o}}^{\mathrm{N}} w_{ij} p_{it}^{m}$. 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 as commonly done in the empirical economics literature on price series where extremes are more likely than a standard normal distribution, and closer to a log-normal one.

The vector of global variables are endogenous in the dominant unit model, i.e., the international maize market model. It is made of 4 variables: $x_{it} = (er_{t}^{ind}, p_{t}^{oil}, p_{t}^{int}, f_{t}^{bdi})'$, where er_{t}^{ind} is the dollar index, and f_{t}^{bdi} is the Baltic Dry Index controlling for freight costs.

4 Model estimates and specification tests

We assess the presence of unit roots with Augmented Dickey–Fuller (ADF) tests as well as better performing unit root t-statistics based on weighted symmetric estimation (WS) of ADF regressions that exploit the time reversibility of stationary autoregressive processes. In most cases, unit root null hypothesis cannot be rejected at the 5% significance level (Table 2). Hence, with the exception of Cape Verde and Burundi, we consider the 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. Both tests fail to reject non stationarity for all global variables except oil.

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. Less than half of country models were found to have at least one cointegration relationship. This denotes a generally weak integration of domestic maize markets with regional and global markets. The average pairwise correlation of price levels and differences across all countries is also low. Albeit low, the correlation across price returns suggest that domestic prices are partly driven by something else than a common trend (Table 4). Almost uncorrelated residuals show that the VECMX are effective in accounting for the common factors driving domestic prices.

A key assumption for the GVAR is the small country hypothesis. No single country should be able to impact global variables. Table 5 reports weak exogeneity tests for countries where cointegration has not been ruled out. The F-test assess the joint significance of the error correction terms in the marginal model of weakly exogenous variables. Weak exogeneity of foreign and global variables cannot be rejected as all cases were found to be non-significant.

Contemporaneous foreign variables coefficients (table 6) 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 3.2% and 5.8% increase of domestic prices within the same month.

[1] Among all major exporters to Africa, Argentinian FOB prices exhibited the highest average correlation with African prices and were therefore retained in the model.

Elasticities are generally positive but low, except for Benin which slightly over reacts to external shocks with a coefficient just above unity. Most coefficients lie within the 0.25-0.6 band, denoting that short run price shock transmission from neighboring trading countries remains significant even in the absence of long run cointegrating relationship.

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

Coefficients Burundi, Ghana, Somalia and Kenya are not significant. South African market has among the smallest sensitivity to African maize trade partners, similar to the one of Cape Verde. This reflects a strong market leader position of a big producer in the first case and geographical remoteness in the second case.

5 Generalized impulse response analysis

By means of generalized impulse response functions (GIRF), we analyze and compare the effect of two shocks. First, a one standard deviation positive increase of South African prices, which are central to the continent's trade network. Second, a one standard deviation of domestic prices in Tanzania, a prominent maize producer in the East African Community.

The full transmission of a one standard error shock in Tanzania to neighboring countries generally takes four months (Figure 2). This shock amounts to a 3.5% increase in domestic Tanzanian prices. It translates into a 1% increase in Zambia and Somalia, Tanzania's second and third biggest trade partners. The median impact in Kenya and Congo is 0.5%. The impulse functions show no response in Burundi and Mozambique, the trade partners with which Tanzania has the least exchange of maize. Burundi trade most of its maize with Uganda and Rwanda whereas Mozambique has tighter maize trade links with South Africa than Tanzania. South Africa shows no reaction to turmoil in Tanzanian markets. Impulse responses for the other countries which are not reported in Figure 2, are close to zero or non-significant.

Compared to the scenario in Tanzania, a one standard deviation shock in South Africa's domestic markets affects more countries. This amounts to a 3% increase in local South African prices (Figure 3). The response is particularly visible in coastal Western African countries connected by maritime routes such as Senegal, Gambia, Cape Verde, Togo, Benin and Nigeria. The response is however much weaker for Ivory Coast and Ghana. Interestingly, even though Burkina Faso does not import a lot from South Africa, the effect of such a shock still penetrates its market albeit with a one or two months delay.

The same shock in Nigeria, a net maize exporter, raises local prices by around 3% but the turbulence almost does not exit the country (Figure 5). We observe limited responses in Senegal, Mali, Niger and Benin, but they are close to and non-significantly different from zero.

A one standard deviation shock to Argentinian export prices amounts to a 2% increase in this major export market. Compared with local equivalents, a price shock from the international market takes on average twice as much time to be fully transmitted. However, most local African markets seem insulated from or not significantly affected by international price shocks, which is not dissimilar from what Minot, 2011 and Baquedano and Liefert, 2014, found. Only connected markets such as South Africa seem to respond to international price shocks and in a faster fashion, owing to their stronger integration with global markets.

Other local markets such as Togo, Nigeria, Mozambique, Gambia, and Cameroon, which are all coastal markets, do seem also connected to Argentinian export prices in a significant way. Some international price shocks which do not directly affect local markets can still have an indirect effect, channeled by direct pass-through to coastal countries, depending on their primary absorption of the shock in the first place.

Finally, we note that when shocks are effectively transmitted to trade partners, they create long lasting deviation of prices from their equilibrium position, except for Gambia.

Other macro-economic shocks could be of key importance to examine. A potential global shock of interest is from the crude oil prices. 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 therefore look at the pass-through effects and impulse responses of local maize markets of a global shock on the US dollar and on crude oil. However, conducting GIRFs analysis to a one-standard deviation positive shock on crude oil prices and a global shock on local exchange rates with the dollar does not exhibit any 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 oil shock, between 0.5 and 1%, was however picked up in countries within the West African block such as Senegal, Gambia, Burkina Faso, Ghana, Togo and Niger, and Ethiopia in Eastern Africa.

6 Conclusion

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. 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. This new modelling framework applied to maize price transmission analysis builds up an approach which enables to clarify regional and local patterns in an attempt to re-center the focus on local markets dynamics.

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. Furthermore, most local markets appear to be significantly more responsive to shocks affecting local trade partners than to global shocks from international markets. We also highlighted price shock channels passing through maritime routes that had been ignored by the literature until now. From a policy perspective, while long run price transmission is a desirable market feature, short term shocks require some level of mitigation. Many of these short term price shocks generate long lasting deviations 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 requires for the root causes to be addressed internally by making production systems and marketing channels more resilient.

On price stabilization and volatility issues, low but significant short term market price transmission is especially a concern for land-locked countries whose food consumption relies on local production and therefore remains vulnerable to tight stocks as well as poor storage infrastructures and policies. 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 undesirable side effects of internal disruptions.

[1] Not included in this manuscript but available upon request.

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Tables

Table 1: Sources and type of prices

GIEWS (15)		WFP (12)	
Wholesale (8)	**Retail (7)**	**Wholesale (2)**	**Retail (10)**
ETH, GHA, MOZ, NGA, RWA, TGO, UGA, ZAF	BEN, CMR, COD, CPV, MWI, SOM, ZMB	KEN, TZA	BDI, BFA, CAF, CIV, GMB, MLI, NER, SEN, TCD, ZWE

Table 2: Unit root statistics for Domestic and Foreign Variables

	p^m		p^{ci}		er		p^{*m}	
	ADF	WS	ADF	WS	ADF	WS	ADF	WS
level (with trend)	26%	22%	26%	13%	8%	12%	11%	4%
level (no trend)	52%	33%	0%	0%	4%	0%	52%	19%
D	89%	93%	57%	61%	92%	96%	100%	100%
DD	100%	100%	100%	100%	100%	100%	100%	100%

Note: proportion of series for which the unit root null hypothesis cannot be rejected at the 5% significance level based on the Augmented dickey fuller (ADF) and (WS) tests.

Table 3: 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	1	Rwanda	3	1	2
Ivory Coast	2	1	1	Senegal	5	2	1
Cameroon	1	2	0	Somalia	4	1	1
Congo	5	3	1	Swaziland	4	2	1
Cape Verde	2	1	0	Chad	1	1	0
Ethiopia	4	2	0	Togo	1	1	0
Ghana	5	3	1	Tanzania	2	1	0
Gambia	1	3	1	Uganda	3	1	0
Kenya	2	1	0	S. Africa	3	1	1
Mali	1	1	0	Zambia	2	1	0
Mozambique	5	1	0				

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 4: Domestic prices average Pairwise Cross-Section Correlations

	Levels	First Differences	VECMX* Residuals		Levels	First Differences	VECMX* Residuals
Burundi	0.243	0.027	0.000	Malawi	0.252	0.035	0.005
Benin	0.374	0.160	0.020	Niger	0.431	0.191	0.001
Burkina Faso	0.455	0.163	0.001	Nigeria	0.398	0.113	0.040
Central Africa	0.279	0.072	0.016	Rwanda	0.423	0.072	0.015
Ivory Coast	0.287	0.095	0.049	Senegal	0.348	0.147	0.008
Cameroon	0.391	0.107	0.018	Somalia	0.321	0.109	0.013
Congo	0.340	0.081	0.011	Swaziland	0.208	0.107	0.047
Cape Verde	0.101	0.129	0.044	Chad	0.355	0.135	0.039
Ethiopia	0.380	0.152	0.041	Togo	0.374	0.181	0.041
Ghana	0.277	0.070	0.010	Tanzania	0.420	0.094	0.008
Gambia	-0.034	0.069	-0.011	Uganda	0.411	0.046	-0.032
Kenya	0.471	0.116	0.025	S. Africa	0.164	0.103	-0.025
Mali	0.390	0.151	0.015	Zambia	0.137	0.016	-0.048
Mozambique	0.257	-0.026	-0.018				

Table 5: F-Statistics for Weak Exogeneity Tests

Country	F test	F crit	p_{it}^{m*}	p_t^{oil}	p_t^{int}	Country	F test	F crit	p_{it}^{m*}	p_t^{oil}	p_t^{int}
Burundi	F(1,99)	3.937	2.94	0.01	0.58	Malawi	F(1,99)	3.94	0.01	0.86	0.43
Benin	F(0,100)					Niger	F(1,99)	3.94	0.02	0.15	0.05
Burkina Faso	F(1,99)	3.937	0.03	0.70	0.03	Nigeria	F(0,100)				
Centr. Africa	F(1,99)	3.937	0.18	0.02	0.02	Rwanda	F(2,98)	3.09	0.40	0.26	5.20
Ivory Coast	F(1,99)	3.937	1.34	0.12	0.33	Senegal	F(1,99)	3.94	0.00	0.43	0.00
Cameroon	F(0,100)					Somalia	F(1,101)	3.94	0.03	0.04	0.00
Congo	F(1,100)	3.936	3.19	0.00	0.50	Swaziland	F(1,100)	3.94	1.15	0.00	0.01
Cape Verde	F(0,100)					Chad	F(0,100)				
Ethiopia	F(0,100)					Togo	F(0,100)				
Ghana	F(1,99)	3.937	0.98	0.01	0.10	Tanzania	F(0,100)				
Gambia	F(1,100)	3.936	0.95	3.34	0.01	Uganda	F(0,100)				
Kenya	F(0,100)					S. Africa	F(1,99)	3.94	0.32	0.63	0.18
Mali	F(0,100)					Zambia	F(0,100)				
Mozambique	F(0,100)										

Note: Critical value for the 5 % level significance. The lag order for the marginal model was selected by AIC.

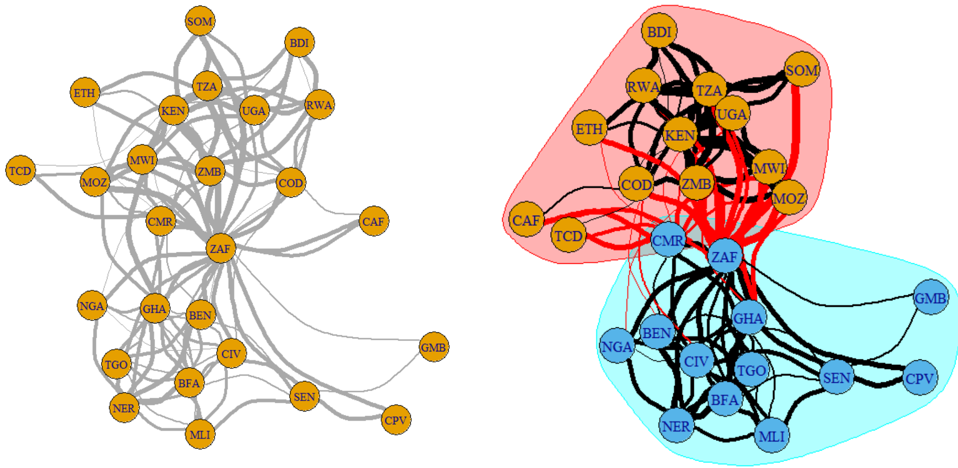
Table 6: Contemporaneous Effects of Foreign Prices on Domestic Counterparts

Country	Coef	SE	Country	Coef	SE
Burundi	-0.142	0.097	Malawi	0.310	0.289
Benin	1.095	0.226	Niger	0.387	0.096
Burkina Faso	0.569	0.140	Nigeria	0.334	0.148
Central Africa	0.577	0.235	Rwanda	0.226	0.154
Ivory Coast	0.613	0.269	Senegal	0.361	0.129
Cameroon	0.280	0.121	Somalia	-0.017	0.166
Congo	0.615	0.254	Swaziland	0.318	0.132
Cape Verde	0.265	0.145	Chad	0.524	0.211
Ethiopia	0.224	0.149	Togo	0.871	0.206
Ghana	-0.052	0.126	Tanzania	0.523	0.203
Gambia	0.580	0.133	Uganda	0.659	0.367
Kenya	0.103	0.153	S. Africa	0.256	0.200
Mali	0.629	0.103	Zambia	0.613	0.171
Mozambique	0.184	0.147			

Note: robust standard errors (SE) computed using White's heteroskedasticity-consistent variance estimator.

Figures

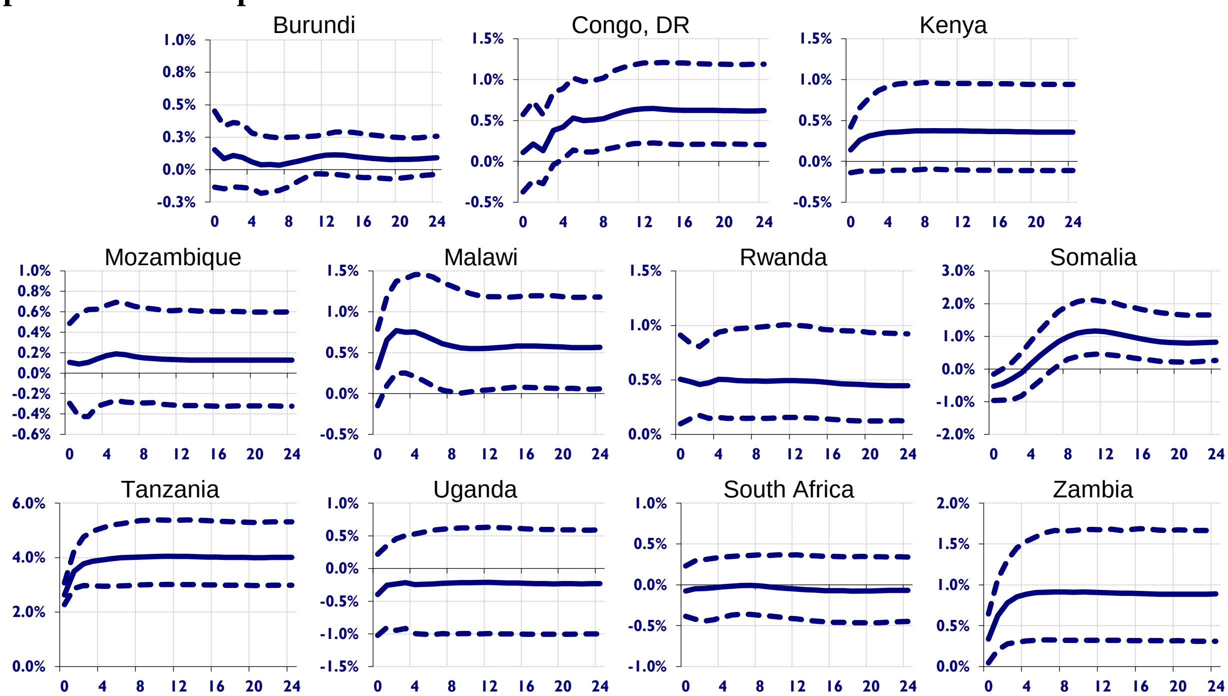
Figure 1: Maize trade network in SSA



a) Maize trade network in Africa b) Trade communities

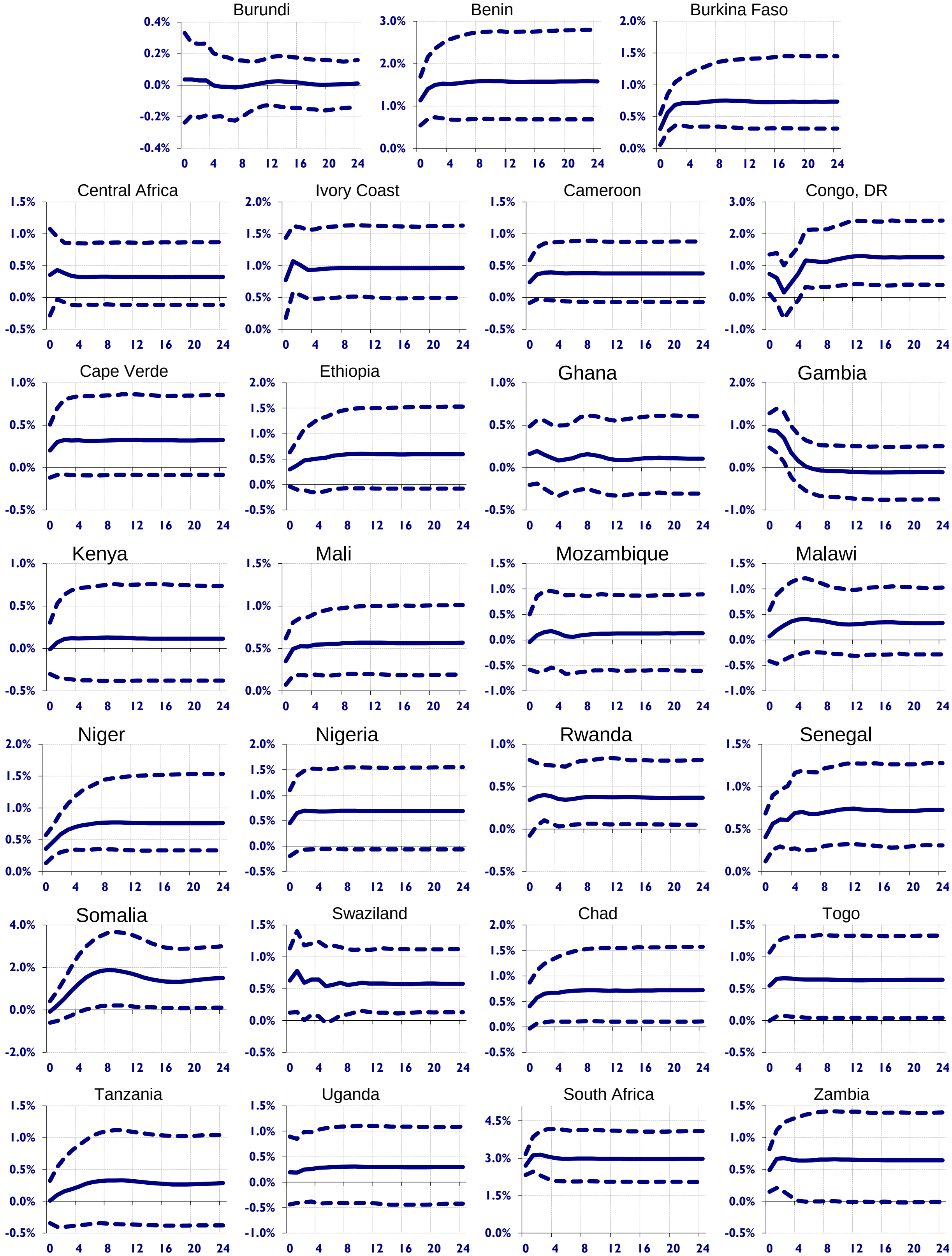
Note: a) Force directed layout of maize trade network. Width of links based on log of total 2005-2014 trade flows from the CEPI/BACI data set. Countries which share more and stronger connections are closer to each other. b) Trade community detection based on edge betweenness (Newman-Girvan algorithm). High-betweenness edges are removed sequentially and the best partitioning of the network is selected.

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



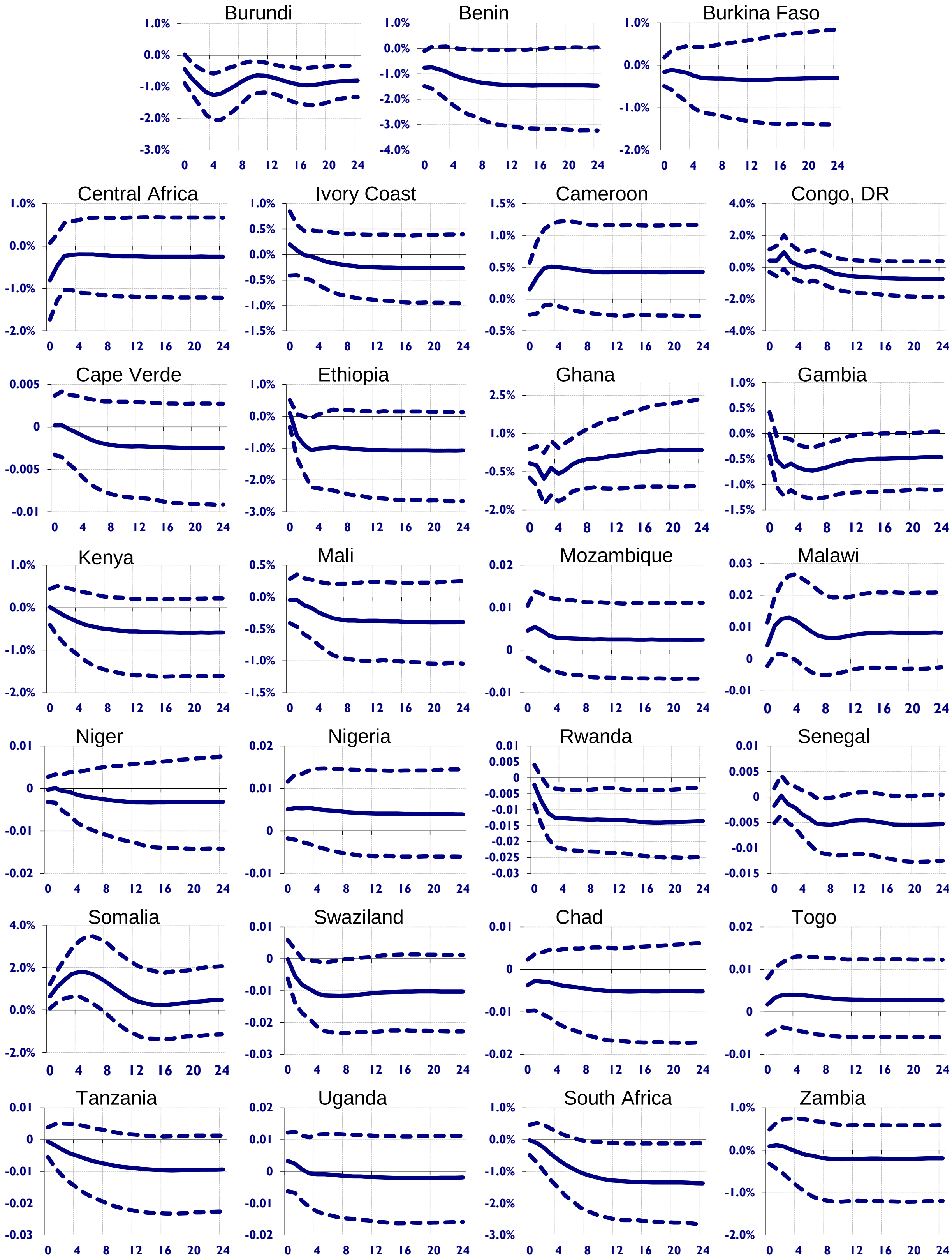
Note: *1200 bootstrap replication mean estimates with 90% bootstrap error bounds. Selected responses of local prices within Tanzania's main trade partners markets*

Figure 3: Domestic prices generalized impulse responses to one standard error positive shock to South African prices



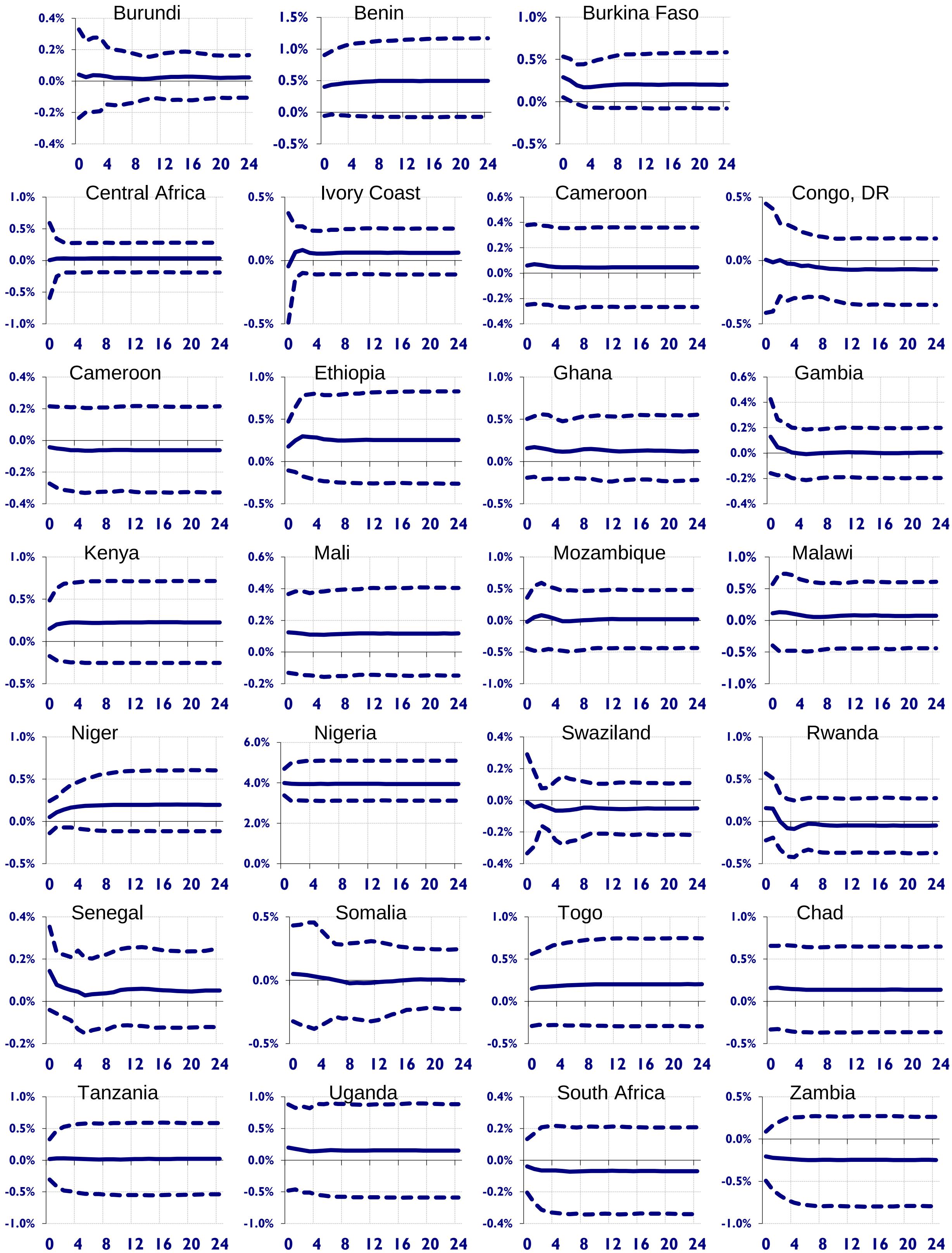
Note: 1200 bootstrap replication mean estimates with 90% bootstrap error bounds

Figure 4: Domestic prices generalized impulse responses to one standard error positive shock to international prices



Note: 1200 bootstrap replication mean estimates with 90% bootstrap error bounds

Figure 5: Domestic prices generalized impulse responses to one standard error positive shock to local prices in Nigeria



Note: 1200 bootstrap replication mean estimates with 90% bootstrap error bounds