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Analysis of Food Commodity Prices in Mozambique before and after the 2007/08 International Food Price Crisis

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EXECUTIVE SUMMARY

Large increases in international cereal prices during the international food price crisis of 2007/08 contributed to dramatic cereal price increases in many developing countries that regularly import grains. Previous research using descriptive analysis has noted that food commodity prices in Mozambique appear to be higher on average since 2008 (Cunguara et al 2012), even though international grain prices began to fall in 2009. In this paper, we use a combination of graphical and time series econometric analysis of monthly retail market price data from Mozambique for a number of food commodities to investigate: (a) the extent to which food commodity prices have risen in Mozambique post-2008; and (b) whether increases in international cereal prices and/or changes in domestic factors appear to explain increases in domestic food commodity prices post-2008. We have four main findings from this analysis.

First, using graphical analysis of real monthly retail prices, we find an upward structural shift in food prices in most rural and urban markets of Mozambique between January 2008 and March 2013. Second, our time series econometric analysis finds an upward shift in urban prices of maize, rice, cowpea and small groundnut since January 2008, though the magnitude of this shift varies by crop and market. Third, with the exception of rice, the international price does not appear to exert much dynamic influence on domestic food crop prices, and thus does not account for the upward shift in prices of commodities other than rice. Fourth, because our analysis controls separately for the international market price of a given commodity, this implies that the upward structural shift in the domestic price of white maize, cowpea, and large groundnut appears to be due to domestic factors, such as increased domestic demand (though there is evidence that the pronounced upward shift in domestic rice prices post-2008 is due to both higher international rice prices and an increase in domestic demand). While this is primarily due to the continued increase in average household income, for the case of maize (cassava), this is also explained at least in part by the arrival of several poultry plants (a brewery of cassava beer) in northern Mozambique soon after 2008.

Because the majority of rural households are net buyers of staple food commodities like maize, rice and beans, higher food prices tend to hurt not only all domestic urban consumers but also the majority of rural households. This begs the question of what is the appropriate role for government in addressing an environment of higher domestic prices of these commodities. There are in fact several public goods that could support stronger supply response from smallholders, which could decrease domestic prices of maize, beans, groundnuts, etc by increasing domestic production levels. One of the most direct ways to reduce prices of commodities that are predominantly supplied by domestic production would be for the government to continue to improve rural roads, thereby reducing one of the primary components of the margins between farm and retail-level prices. Improved rural roads would also provide even higher farm-gate prices to farmers, which would further incentivize them to increase their crop production, while also reducing input costs for both farm and non-farm activities. Another key investment would be for the government to help farmers north of the Zambezi river to expand their cultivated area by gaining access to animal traction. The adoption of large livestock in northern Mozambique, currently at less than 1% of all households, would require a number of investments (Cunguara et al 2016), such as (a) testing for trypanosomiasis prevalence; (b) providing livestock extension on large livestock-keeping; (c)

subsidizing access to trypanosomiasis treatment wherever its prevalence is clearly a key constraint. However, access to animal traction would enable smallholder farmers in the medium- to high-potential zones in northern Mozambique to expand their cultivated area and gain access to manure, which has been shown to have a significant positive effect on yields of several crops (Mather et al, 2015).

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This report does not reflect the official views or policy positions of the Government of the Republic of Mozambique nor of USAID. Any errors are the sole responsibility of the authors.

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ACRONYMS

F.O.B.	Free (or Freight) on Board
INE	Instituto Nacional de Estatística (National Statistics Institute)
MTN	New Metical
SEM	Structural Equations Model
SIMA	Sistema de Informação de Mercados Agrícolas (Agricultural Market Price Information System)
VAR	Vector Auto-Regression

1. INTRODUCTION

It is well known that there was a dramatic rise of international cereal prices in 2007/08, often referred to as the international food price crisis. Most analysts believe that this spike in cereal prices was caused by a combination of factors, including: (i) increasing demand for grains (for animal feed in China/India; biofuels in developed countries); ii) a combination of crop failures in many countries; (iii) in the case of rice, the effect of crop failures among traditional exporters on international market prices was exacerbated by export bans imposed by those country's governments. The large increases in international cereal prices in 2007/08 contributed to dramatic cereal price increases in many developing countries that regularly import grains. These price increases in turn led to adverse effects on the welfare of poor urban and rural households and, in some cases, political unrest. Although international prices of many commodities fell somewhat by 2009, the demand factors noted above remain strong.

Previous research using descriptive analysis has noted that the retail market prices of a number of key food commodities appear to be higher on average since 2008 (Cunguara et al 2012), even though international grain prices began to fall in 2009. In this paper, we use a combination of graphical and time series econometric analysis of monthly market price data of a number of food commodities to investigate the following empirical questions with respect to food prices in Mozambique.

1) To what extent did food crop prices rise in Mozambique in 2007/08 and afterward, and does Mozambique appear to be in a 'higher food price environment' post-2008?
2) What was/is the role of international price increases relative to increases in domestic demand in determining domestic prices? For example, while it is well-known that Mozambique rice prices are likely very sensitive to international price environment – how sensitive are domestic prices of white maize, beans or groundnuts to changes in international market prices?
3) To what extent are post-2008 price increases due to domestic factors, such as increased demand for maize from new large poultry agribusinesses in the North and increased demand for cassava flour from a brewery in Nampula?

The paper is organized as follows. In Section two, we describe the data sources used and Section three our methods. In Section four, we present results of graphical price analysis and time series econometric analysis in Section four. We then offer conclusions and policy implications in section five.

2. DATA

Monthly retail prices (MTN/kg) for a variety of food commodities (white maize, milled rice, cowpea, common mean, small groundnut, cassava flour, etc) in domestic markets comes from SIMA (2013). International commodity prices come from SAFEX (white maize) and the World Bank pink sheet commodity prices (Thai 5%, oil index).

The import parity price for white maize is computed as the white maize price reported by SAFEX, plus estimated shipping charges from South Africa to Maputo (by truck). We scale the petrol component of shipping using an oil index from the World Bank pink sheets commodity prices.[1] The import parity price of rice is computed as the F.O.B. price of Thai 5% rice from the World Bank pink sheet commodity prices, plus estimated shipping, port, insurance, and handling costs based on a time series of such data from the U.S. Gulf Coast to Durban, South Africa from the Chicago Board of Trade.

We convert international prices to domestic currency (MTN) using historical exchange rates from www.oanda.com. We convert all nominal price series to real[2] MTN (April 2011) using a regional consumer price index from the Instituto Nacional de Estatistica (INE).

[1] We use the historical monthly price series from the World Bank pink sheet commodity price webpage http://www.worldbank.org/en/research/commodity-markets

[2] ‘Real’ prices are prices that are adjusted for inflation.

3. METHODS

3.1 Descriptive and graphical analysis

We begin by using graphical analysis of real monthly food prices from as many urban and rural markets covered by SIMA as possible, given market price data availability. For our purposes, in order to use price data from a given market, the data needs to record prices with sufficient frequency (price observations in at least 10 out of 12 months of the year) throughout the time period of our analysis (2000-2012). We then have Stata fit trend lines in the graphs for two time periods: Jan 2000 to Dec 2007, and Jan 2008 to March 2012. These trend lines help us to visually inspect for shifts (or not) in average prices between those two time periods.

3.2 Time series econometric analysis

We next use time series econometric analysis in order to assess the influence of changes in both international and domestic market prices on domestic food crop prices in Mozambique over time. Two econometric approaches could be used to assess the impact of structural changes on prices: a structural simultaneous equations model (SEM) or a vector auto-regression (VAR) model. Implementation of the SEM of supply, demand and price determination relationships requires that a set of assumptions about the underlying economic structure is imposed prior to estimation. As suggested that Myers, Piggott and Tomek (1990), SEM requires substantial certainty regarding the underlying economic structure driving the data generating process. This assumption makes SEM less attractive for our application to Mozambique because we are faced with substantial uncertainty regarding the economic structure that drives determination of agricultural commodity prices in the country. In addition, limited data availability – especially time series data on storage volumes, quantities consumed, input prices and prices of competing commodities – also poses significant challenges to implementing an SEM for Mozambique.

By contrast, VAR modelling has proved to be an attractive alternative approach when researchers are faced with limited data to build a full structural econometric model. Another advantage of VAR modeling is that fewer structural identification restrictions are imposed under the VAR approach, compared with the SEM approach. For these reasons, the VAR modeling was the approach chosen for this study. We employed the structural VAR framework used in the literature to estimate the effect of food price policies (e.g. Myers, Piggott and Tomek, 1990; Jayne, Myers and Nyoro, 2008; Mason and Myers, 2013). The main disadvantage of the VAR approach is that some factors that might influence price determination are left out of the VAR specification.

We estimate VAR models for several agricultural commodities in Mozambique, though all the models have the same similar structure as outlined here. Two types of prices are included in our VAR specification: international prices and a vector of domestic prices in month t, denoted respectively by y_t and $\mathbf{p}_t$. These prices are modeled as endogenous variables. Our graphical analysis of domestic prices for agricultural commodities and market observations suggested that there is a substantial increase in domestic prices starting in January 2008. To capture this potential structural changes in domestic prices, we include in the VAR specification an exogenous dummy variable, D_t, equal to one for the period January 2008 onward and equal to zero otherwise. In addition to the intercept, we also included an exogenous seasonal component in the deterministic part of our VAR specification. This is because prices for agricultural commodities follow seasonal patterns. We modeled seasonality using the Fourier approximation because it allows for flexibility in the seasonal pattern which is represented as a linear combination of sine and cosine functions. This is an advantage especially when the seasonal pattern is unknown. Our VAR dynamic model is specified as

$$\begin{aligned} y_t &= \mathbf{A}^y \mathbf{z}_t^y + \sum_{i=1}^{k} \beta_i y_{t-i} + \sum_{i=0}^{k} \mathbf{B}_i \mathbf{p}_{t-i} + \delta D_t + u_t^y \\ \mathbf{C}\mathbf{p}_t &= \mathbf{A}^{\mathbf{p}} \mathbf{z}_t^{\mathbf{p}} + \sum_{i=0}^{k} \gamma_i y_{t-i} + \sum_{i=1}^{k} \mathbf{G}_i \mathbf{p}_{t-i} + \mathbf{S}\mathbf{v}_t + \mathbf{T}^{\mathbf{p}} \mathbf{u}_t^{\mathbf{p}} \end{aligned} \tag{1}$$

where $\mathbf{z}^y$ and $\mathbf{z}^{\mathbf{p}}$ are vectors of deterministic components representing the constant term and seasonal components; $\mathbf{v}_t$ denotes a vector of dummy variables associated with the structural change in prices; u_t^y and $\mathbf{u}_t^{\mathbf{p}}$ are vectors of mutually uncorrelated random shocks to each endogenous variable in the VAR model; and $\mathbf{A}^y$, $\mathbf{B}_i$, β_i, δ and $\mathbf{C}$, $\mathbf{A}^{\mathbf{p}}$, γ_i, $\mathbf{G}_i$, $\mathbf{S}$, $\mathbf{T}^{\mathbf{p}}$ represent matrices of unknown parameters to be estimated.

Prior to estimation of the system of equations (1), we imposed recursive ordering – commonly known as Cholesky decomposition[3] – to identify parameters associated with the contemporaneous variables, while no restrictions are imposed on the dynamic relationships between the variables captured by the lagged variables. Recursive ordering requires that $\mathbf{B}_0 = \mathbf{0}$, $\mathbf{C}$ be lower triangular matrix with ones along the diagonal and $\mathbf{T}^{\mathbf{p}}$ be a lower triangular matrix. This implies that contemporaneous international prices are not influenced by contemporaneous changes in domestic prices. However, the effects of domestic prices on contemporaneous international prices are channeled through lagged domestic prices, which are left unrestricted. Our VAR specification allows for contemporaneous domestic prices to be influenced by current and lagged values of international prices. For prices in domestic markets, we ordered the largest and most liquid market first followed by the less important markets in terms of size and liquidity.

For example, the structural VAR (SVAR) of white maize consists of endogenous variables (prices from SAFEX, Maputo, Chimoio, Nampula) and exogenous variables (sine and cosine functions to model the annual seasonality of food crop prices; a shift binary variable that =0 from 1998 to Dec 2012; =1 in Jan 08 and after). Based on the size and liquidity of markets we use in the analysis for maize, we assume the following recursive ordering between market prices: SAFEX → Maputo → Chimoio → Nampula. For example, the contemporaneous SAFEX price is not affected by domestic prices in Mozambique, but is affected by lags of all endogenous prices. The contemporaneous Maputo price is affected by the current SAFEX price and lags of all endogenous prices. Next, the Chimoio price is affected by the current SAFEX and Maputo price, and lags of all endogenous prices. Finally, the contemporaneous Nampula price is affected by the contemporaneous prices from SAFEX, Maputo, and Chimoio, as well as lags of all endogenous prices. Please see Appendix A for discussion of the recursive ordering of other food crop prices.

Lag lengths were selected using the following procedure. First, we use the varsoc command in Stata, which reports 5 common statistics: Final prediction error (FPE), Akaike's Information Criterion (AIC), Schwarz's Bayesian Information Criterion (SBIC), Hannan and Quinn

[3] See Jayne et al (2008) for discussion of the Cholesky decomposition approach.

Information Criterion (HQIC) and Likelihood Ratio Test (LRT). Second, we proceed by starting with the lower lag length suggested by the information criteria, and we run a VAR and test the residuals for autocorrelation using the Durban-Watson-alternative test. If statistically significant evidence of autocorrelation is found in any residual, then we increase the lag length by one and repeat the procedure until no additional autocorrelation is found. We then use an Augmented Dickey-Fuller test to test for stationarity of each price series.

After estimation of the unknown parameters in the VAR models, we simulate what domestic price levels would have been in the absence of a structural change in prices. This is achieved by setting the dummy variables for the structural change to zero in all equations in the system throughout the sample period and then recursively estimating prices in domestic markets. During the simulation, we keep international prices at their historical levels. This is because we are interested in estimating the effect of the structural change in domestic markets and not changes in international markets. In doing this, we are assuming that the dummy "shift" variable is in fact capturing the effect of structural change in domestic markets, and not a change in perhaps both domestic and international markets. We then compute the percentage difference between historical and simulated prices as our measure of the effects of the structural change on domestic prices.

Finally, we use an impulse response function (IRF) to assess the sensitivity of a given market price to a specified percentage change in (a) the international price of the commodity and then (b) the structural change shift variable. For example, if we program a 10% one-period increase (i.e. shock) in the international price, for how many months will this one-time shock affect the price of maize in Maputo?

4. RESULTS

4.1 Graphical price analysis

Across the graphs of real domestic retail market prices, the prices of each commodity we investigated were on average higher in most markets between 2008-2012 when compared with the average price between 2000-2007 (Figures 2 through 7). The most dramatic increase during the 2008-2012 period is seen for the domestic price of rice, which is predominantly imported (Figure 2).

Figure 1 Monthly retail market prices of white maize (real MTN/kg), 2000-2012

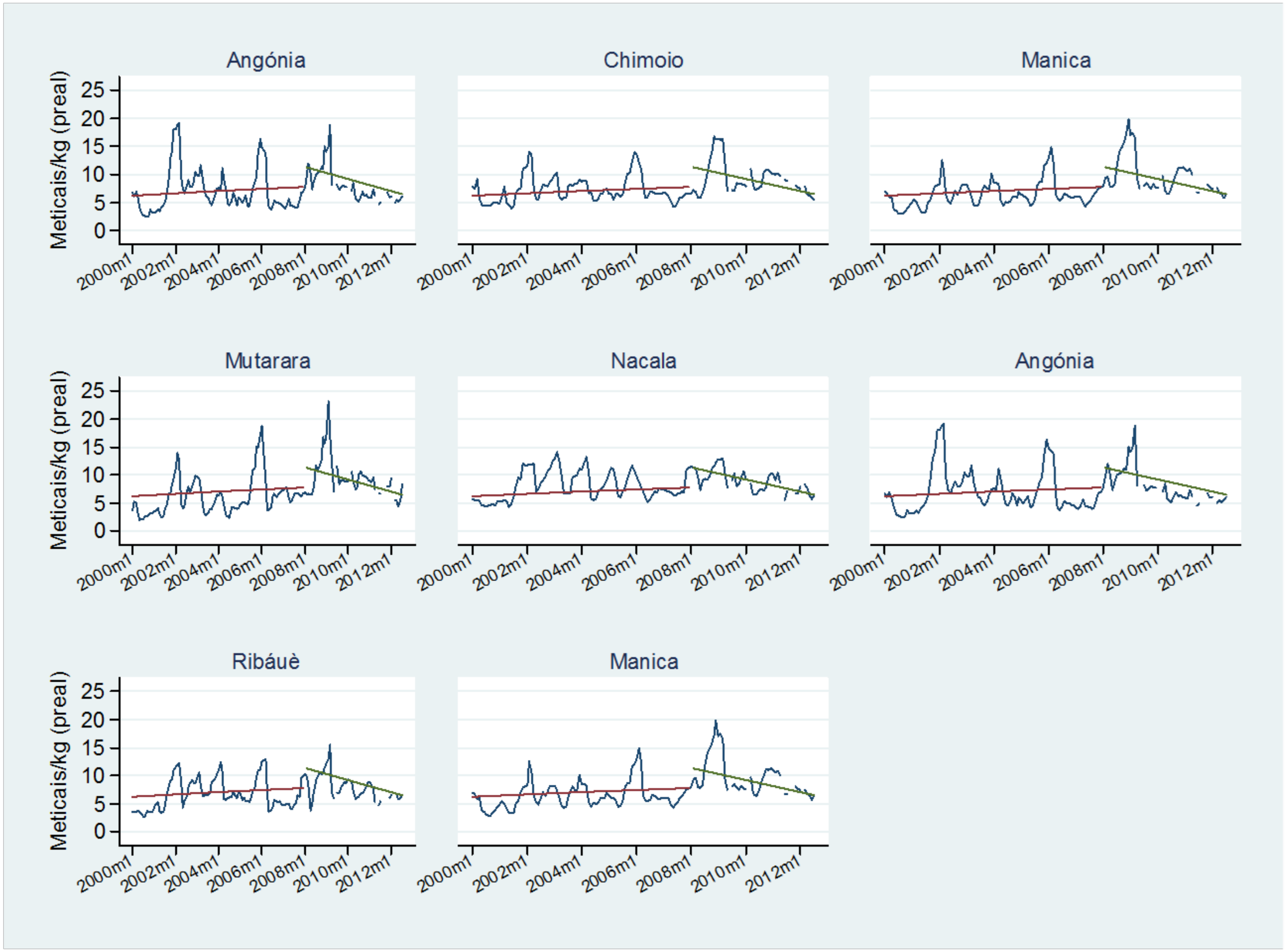


Figure 2 Monthly retail market prices of rice (real MTN/kg), 2000-2012

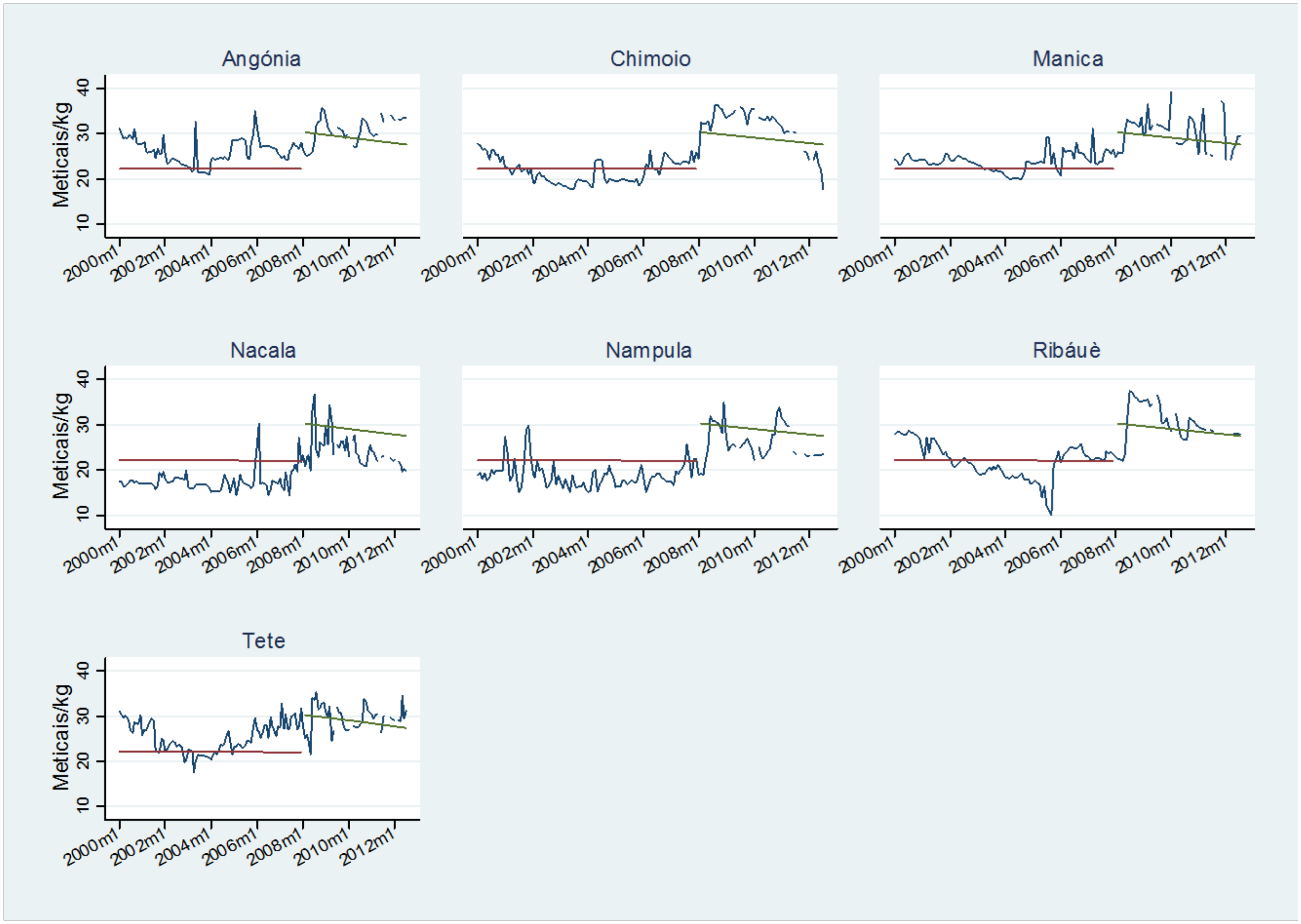


Figure 3 Monthly retail market prices of cowpea (real MTN/kg), 2000-2012

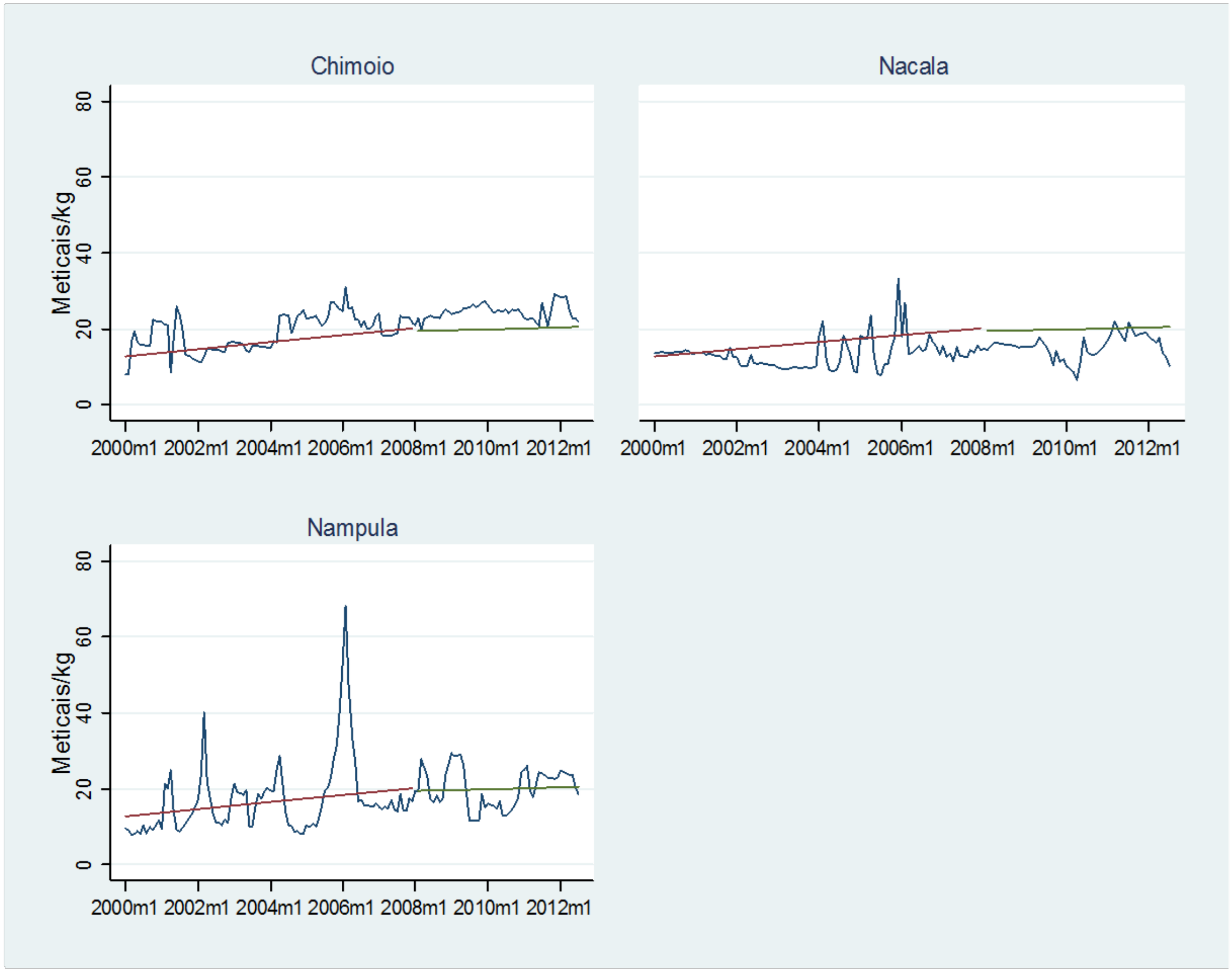


Figure 4 Monthly retail market prices of common bean (real MTN/kg), 2000-2012

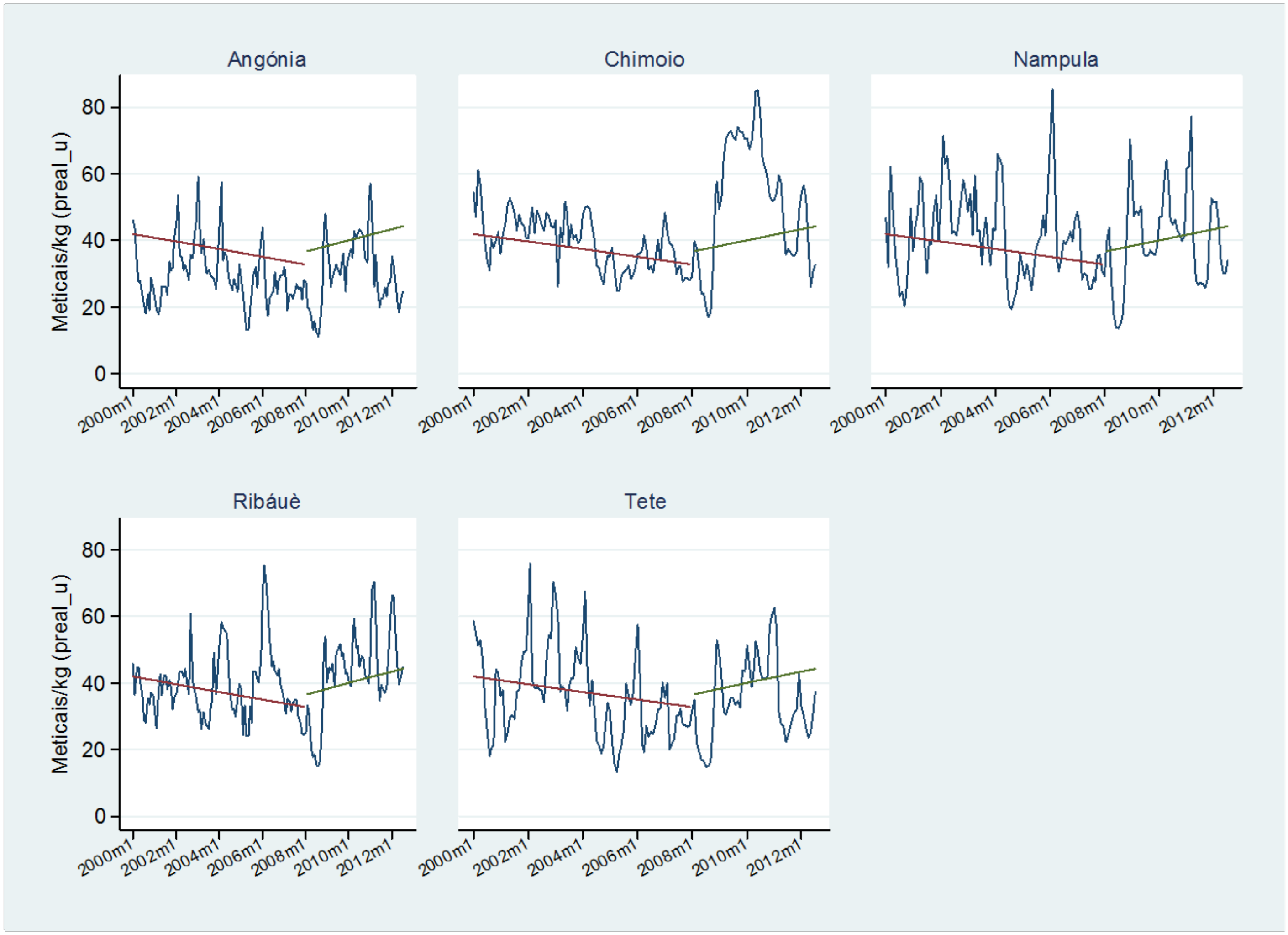


Figure 5 Monthly retail market prices of large groundnut (real MTN/kg), 2000-2012

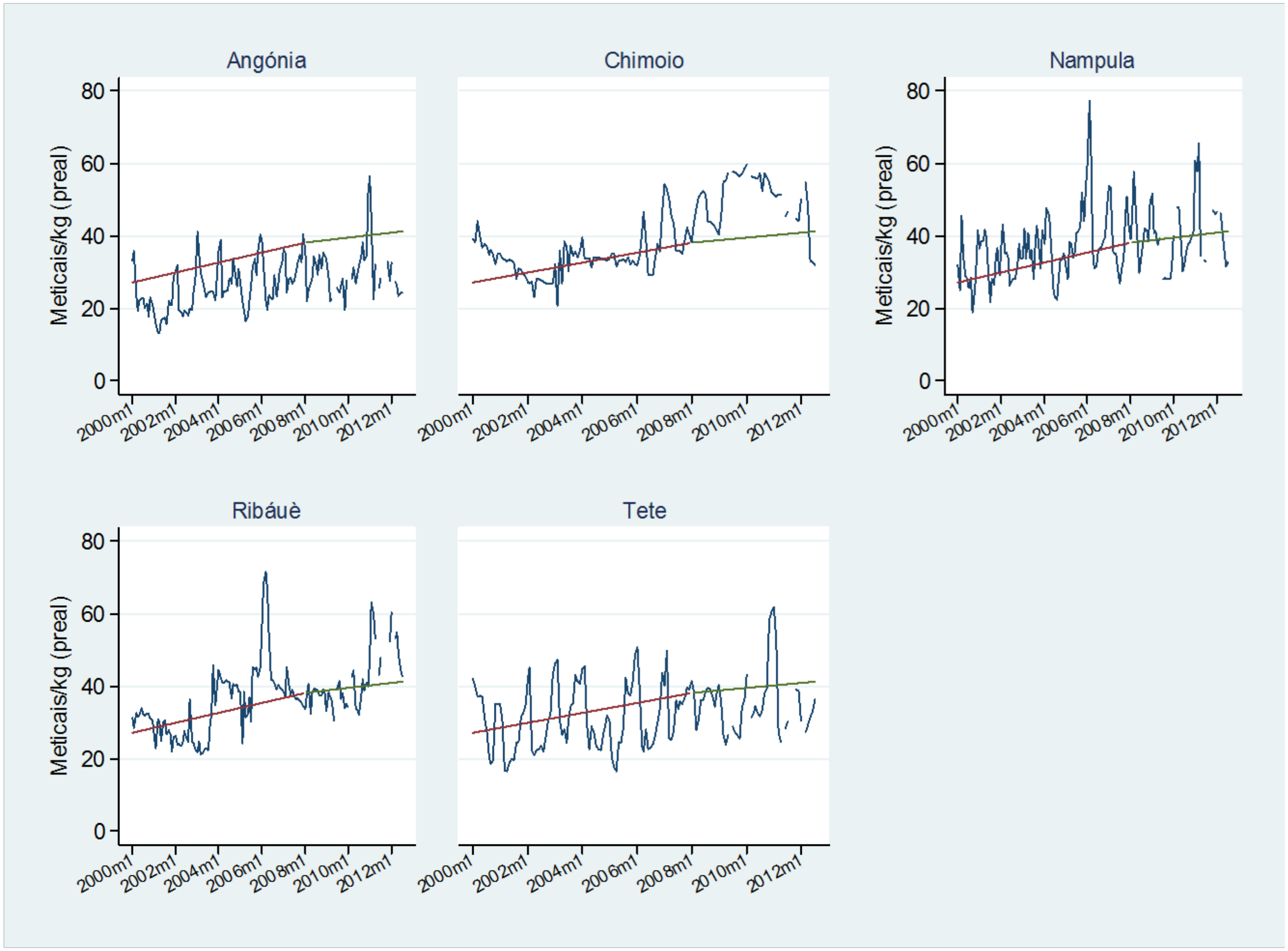


Figure 6 Monthly retail market prices of small groundnut (real MTN/kg), 2000-2012

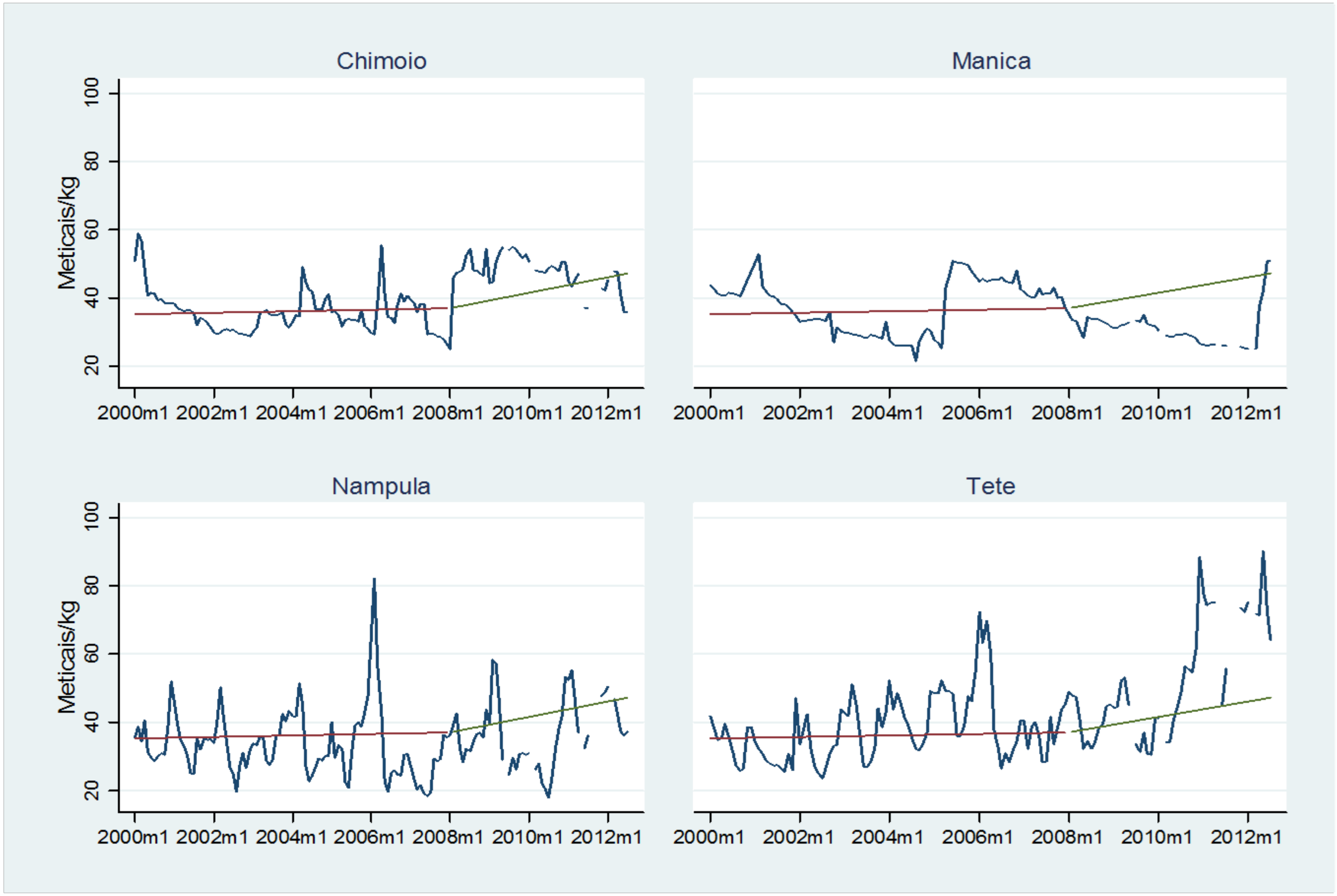
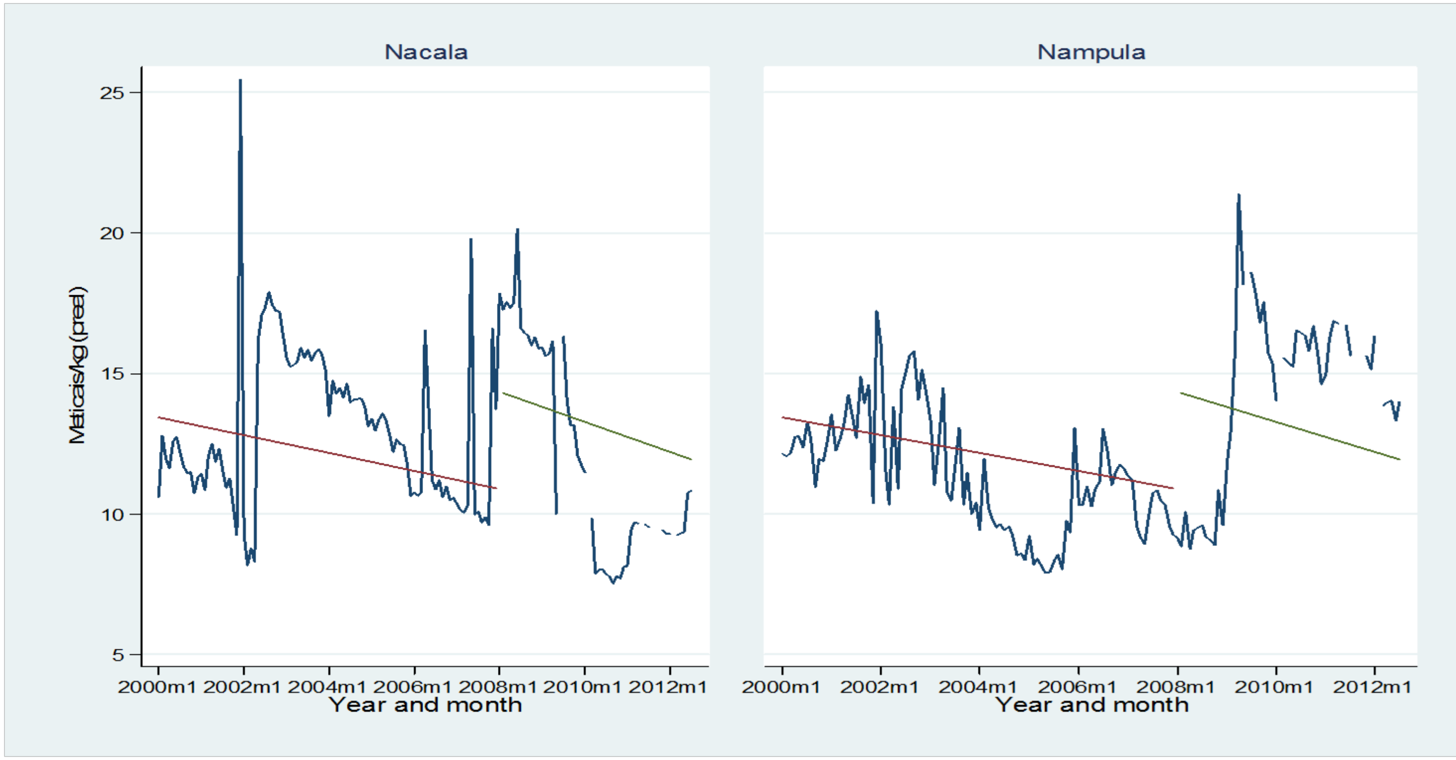


Figure 7 Monthly retail market prices of cassava flour (real MTN/kg), 2000-2012



4.2. Econometric Analysis

4.2.1 Maize prices

We find that each of the maize price series are stationary with a lag of 2 months. We then simulate a 7% increase in the SAFEX price to measure the extent of the effect of the international price of maize on domestic retail market prices of maize. We find that the SAFEX price does not have significant (i.e. p-value is >0.10) *direct* dynamic effect on domestic maize prices in Maputo, Chimoio, or Nampula. However, we find that the dummy variable that =1 from January 2008 onward does have a significant effect on the Maputo price (p=0.000).

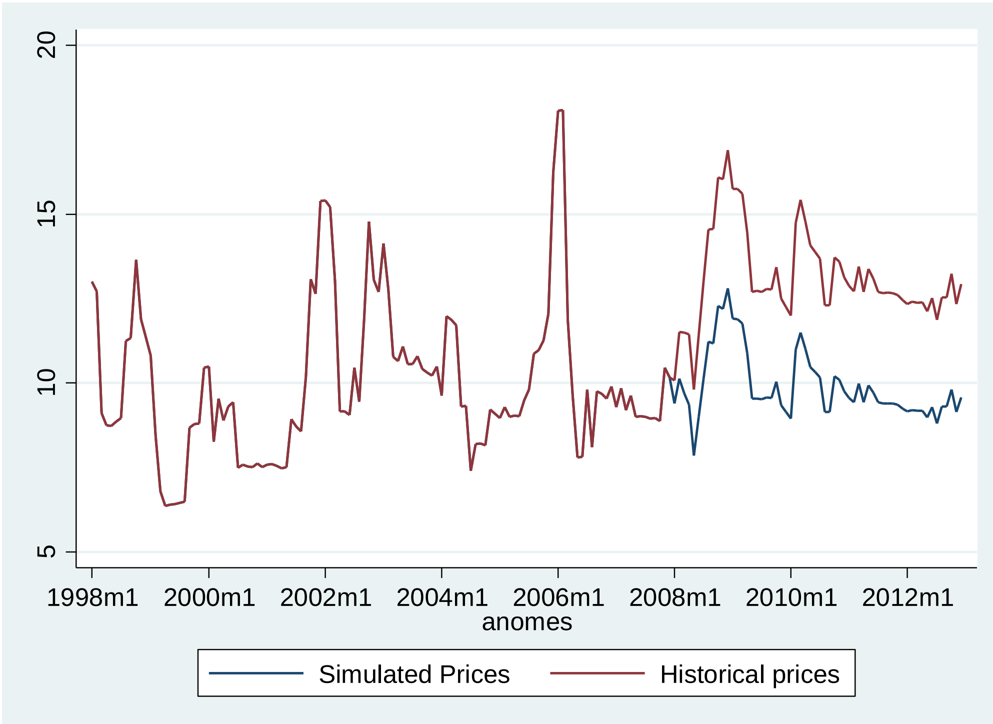
We then simulate what domestic price levels during 2008-2012 would have been in the absence of the structural change in prices noted above (i.e. when we set the dummy shift variable =0 during the 2008-2012 period). The difference between historical prices and simulated prices (without the shift component) provides a measure of the effect of the structural shift on domestic prices. For example, the average historical price of maize from 2008-2012 during this time period in Maputo was 13.1 MTN/kg, while the simulated price is 9.9 MTN/kg, which is 24.5% lower than the historical price (Table 1). This upward shift is seen in a graph of historical and simulated prices from Maputo between 2000-2012 (Figure 8), where we use prices from the second simulation to remove the effect of the dummy "shift" variable from historical prices.

Table 1 Mean historical and simulated maize prices 2008-2012

	Mean maize prices (2008-12)			
	Maputo	Chimoio	Nampula	SAFEX
Historical prices	13.1	9.4	9.3	9.2
Simulated prices	9.9	6.9	7.9	8.9
% price variation	-24.5%	-27.2%	-14.4%	-3.6%

These results of time series econometric analysis of retail market prices of maize in three key markets in Mozambique have two implications. First, the upward shift seen in maize prices in a number of rural retail markets across Mozambique beginning in 2008 (Figure 1) are not caused by increases in international maize prices from 2008 to 2012. Second, the significance of the dummy 'shift' variable means that there has been an upward shift in the retail prices of maize in Mozambique due to factors other than international maize market prices, which implies a change in domestic factors. As noted above, our model cannot tell us what the significant effect of the upward shift variable is capturing, although because we are controlling separately for the relevant international price of maize for Mozambique (as an exogenous variable), the implication is that the upward shift variable is capturing a change in domestic factors that affect domestic prices. For example, several changes in basic factors of domestic demand for maize may explain the upward shift in maize prices since January 2012; first, there has been continued growth in mean household incomes during this time period; second, a number of poultry plants were been built and been active in northern Mozambique since 2008. Thus, it appears that increased domestic demand for maize has caused the upward shift in average maize market prices since 2008.

Figure 8 Historical and simulated monthly maize prices (real MTN/kg), Maputo 2000-2012



4.2.2 Rice prices

We find that the Nampula price series is stationary with one lag, but those for "Thai 5%", Maputo and Chimoio are non-stationary. We then simulate a 10% increase in the Thai 5% (international rice price) to measure the extent of the effect of the international price of rice on domestic retail market prices of rice. We find that the international rice price has a large direct dynamic effect on domestic rice prices in Maputo. Unfortunately, because of the non-stationarity of several of these price series, we are not able to test the significance of this effect.[4] In addition, we note that the international rice price is clearly higher on average post-2008, as is the Maputo price (Figure 9).

We also find that the dummy variable that =1 from January 2008 onward has a positive effect on the Maputo and Nampula prices (though we can't test the significance of these effects). For example, when we simulate what domestic price levels during 2008-2012 would have been in the absence of any structural change in rice prices (i.e. when we set the dummy shift variable =0 during the 2008-2012 period), there clearly appears to have been an upward structural shift in domestic prices. For example, the average historical price of rice from 2008-2012 during this time period in Maputo was 25.5 MTN/kg, while the simulated price is 17.5 MTN/kg, which is 31.2% lower than the historical price (Table 2). These two results suggest that the very clear upward shift in

[4] Due to the non-stationarity of some of the rice price series, we would need to use an Error Correction Model to run a SVAR of rice prices in order to run a simulation with unbiased standard errors. However, our time-series econometric software (Stata) does not permit us to run an ECM with an exogenous variable, and running a simulation requires one to write considerable syntax, which is beyond the scope of this paper for us to do in E-views.

real rice prices post-2008 in various markets in Mozambique (Figure 2) is due to both the effect of a higher international price of rice and an increase in domestic demand for rice post-2008.

Figure 9 Monthly process from Maputo and Thailand 5% (real MTN/Kg), 2000-2012

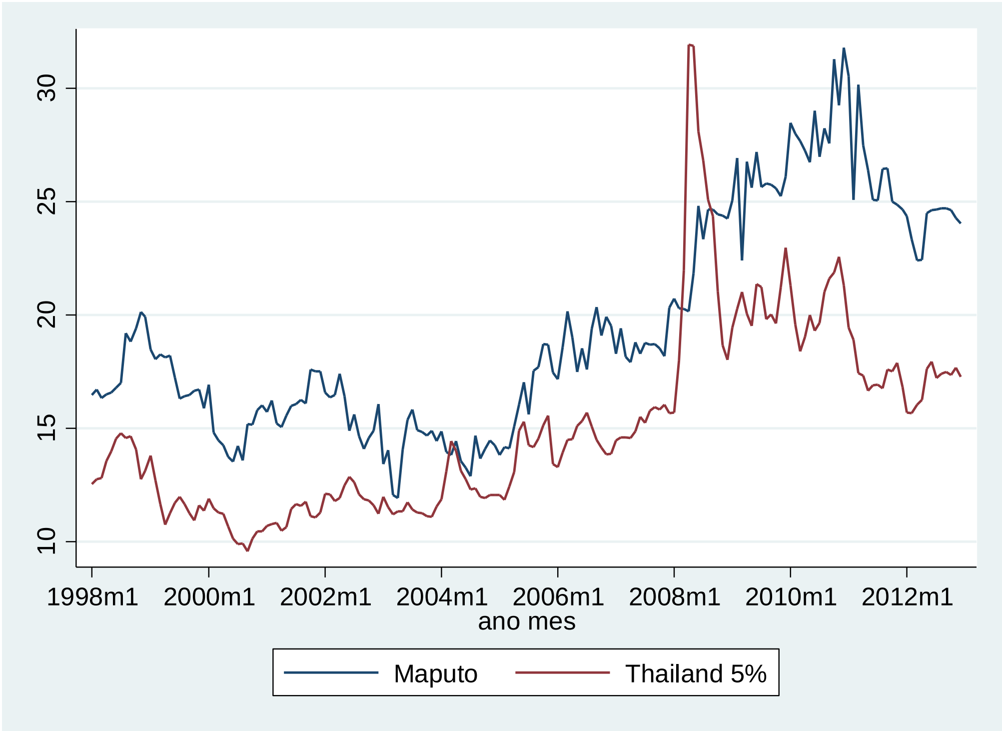


Table 2 Mean historical and simulated rice prices 2008-2012

	Mean rice prices (2008-12)			
	Maputo	Chimoio	Nampula	Thai 5%
Historical prices	25.5	31.0	26.0	19.8
Simulated prices	17.5	25.4	20.9	13.1
% price variation	-31.2%	-18.0%	-19.5%	-33.7%

4.2.3 Cowpea prices

We find that each of the cowpea prices are stationary. Because cowpea appears to not be imported in any significant quantities, we run the VAR using only domestic prices. We find that the dummy variable that =1 from January 2008 onward has a significant effect on the price in both Maputo and Chimoio. We then simulate what domestic price levels during 2008-2012 would have been in the absence of this structural change in prices. The average historical price of cowpea from 2008-2012 during this time period in Maputo (Chimoio) was 23.7 MTN/kg, while the simulated price is 19.7 MTN/kg, which is 16.7% (31.4%) lower than the historical price (Table 3).

Table 3 Mean historical and simulated cowpea prices 2008-2012

	Mean cowpea prices (2008-12)		
	Maputo	Chimoio	Nampula
Historical prices	23.7	25.0	20.9
Simulated prices	19.7	17.1	16.4
% price variation	-16.7%	-31.4%	-21.4%

4.2.4 Large groundnut prices

We find that each of the large groundnut prices are stationary, including an international price (from Holland). We find that 5% increase in international groundnut price does not have significant dynamic effect on domestic large groundnut prices (Maputo, Chimoio, Nampula). However, we find that the dummy variable that =1 from January 2008 onward does have a significant effect on the groundnut price in Chimoio. This is seen clearly when we simulate prices with and without the structural shift dummy variable. For example, the average historical price of large groundnut from 2008-2012 during this time period in Chimoio was 4.7 MTN/kg, while the simulated price is 3.3 MTN/kg, which is 28.3% lower than the historical price (Table 4).

Table 4 Mean historical and simulated large groundnut prices 2008-2012

	Mean prices of large groundnut (2008-12)			
	Maputo	Chimoio	Nampula	Holland
Historical prices	3.9	4.7	3.9	5.3
Simulated prices	3.3	3.3	3.6	4.8
% price variation	-15.0%	-28.3%	-8.3%	-8.7%

5. CONCLUSIONS

Large increases in international cereal prices during the international food price crisis of 2007/08 contributed to dramatic cereal price increases in many developing countries that regularly import grains. Previous research using descriptive analysis has noted that food commodity prices in Mozambique appear to be higher on average since 2008 (Cunguara et al 2012), even though international grain prices began to fall in 2009. In this paper, we use a combination of graphical and time series econometric analysis of monthly retail market price data from Mozambique for a number of food commodities to investigate: (a) the extent to which food commodity prices have risen in Mozambique post-2008; and (b) whether increases in international cereal prices and/or changes in domestic factors appear to explain increases in domestic food commodity prices post-2008. We have four main findings from this analysis.

First, using graphical analysis of real monthly retail prices, we find an upward structural shift in food prices in most rural and urban markets of Mozambique between January 2008 and March 2013. Second, our time series econometric analysis finds an upward shift in urban prices of maize, rice, cowpea and small groundnut since January 2008, though the magnitude of this shift varies by crop and market. Third, with the exception of rice, the international price does not appear to exert much dynamic influence on domestic food crop prices, and thus does not account for the upward shift in prices of commodities other than rice. Fourth, because our analysis controls separately for the international market price of a given commodity, this implies that the upward structural shift in the domestic price of white maize, cowpea, and large groundnut appears to be due to domestic factors, such as increased domestic demand (though there is evidence that the pronounced upward shift in domestic rice prices post-2008 is due to both higher international rice prices and an increase in domestic demand). While this is primarily due to the continued increase in average household income, for the case of maize (cassava), this is also explained at least in part by the arrival of several poultry plants (a brewery of cassava beer) in northern Mozambique soon after 2008.

Because the majority of rural households are net buyers of staple food commodities like maize, rice and beans, higher food prices tend to hurt not only all domestic urban consumers but also the majority of rural households. This begs the question of what is the appropriate role for government in addressing an environment of higher domestic prices of these commodities. There are in fact several public goods that could support stronger supply response from smallholders, which could decrease domestic prices of maize, beans, groundnuts, etc by increasing domestic production levels. One of the most direct ways to reduce prices of commodities that are predominantly supplied by domestic production would be for the government to continue to improve rural roads, thereby reducing one of the primary components of the margins between farm and retail-level prices. Improved rural roads would also provide even higher farm-gate prices to farmers, which would further incentivize them to increase their crop production, while also reducing input costs for both farm and non-farm activities. Another key investment would be for the government to help farmers north of the Zambezi river to expand their cultivated area by gaining access to animal traction. The adoption of large livestock in northern Mozambique, currently at less than 1% of all households, would require a number of investments (Cunguara et al 2016), such as (a) testing for trypanosomiasis prevalence; (b) providing livestock extension on large livestock-keeping; (c) subsidizing access to trypanosomiasis treatment wherever its prevalence is clearly a key constraint. However, access to animal traction would enable smallholder farmers in the medium- to high-potential zones in northern Mozambique to expand their cultivated area and gain access to manure, which has been shown to have a significant positive effect on yields of several crops (Mather et al, 2015).

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APPENDIX A

Assumed recursive ordering for Rice
Thai → Maputo → Chimoio → Nampula

We assume this ordering because most rice in Mozambique is imported, and Maputo is the largest market for rice.

Assumed recursive ordering for cowpea
Nampula → Chimoio → Maputo

We assume this ordering because while cowpea is grown by many farmers in the south, very few of them sell. Most of the cowpea sellers are in the North and in Tete. Thus, we assume that the Nampula market would not likely be affected by prices to the south, though Chimoio would be affected by the north (Nampula), and Maputo by both Chimoio and Nampula. We do not include international prices as SIMA records imports only in the Maputo market.

Assumed recursive ordering for common bean
Nampula → Chimoio → Maputo

Beans are primarily grown and sold in the north (Nampula) and in Tete (Center/Chimoio), thus, we assume that the Nampula market would not be affected by prices in the center (Chimoio) or the south. Likewise, the Chimoio price would be affected by Nampula but not Maputo. We do not include international prices as SIMA records imports only in the Maputo market.

Assumed recursive ordering for small groundnut
Nampula → Chimoio → Maputo

Like cowpea, small groundnut is not sold by as many growers as common bean. We assume that the Nampula market would not likely be affected by prices to the south, though markets in Chimoio would likely be affected primarily by markets in the north (Nampula), while Maputo would be affected by both the Nampula and Chimoio price.