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Food price volatility in developing countries and its determinants

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FOOD PRICE VOLATILITY IN DEVELOPING COUNTRIES AND ITS DETERMINANTS

Abstract

The work at hand contributes to the ongoing discussion on the drivers of food price volatility. Based on theoretical considerations, economical, agricultural, and political determinants of domestic price volatility are identified and discussed. A dynamic panel is estimated to account for country fixed effects and persistence of volatility. Two approaches are followed in order to consistently estimate the impact of time-invariant variables. First, system GMM using levels instead of first differences and, second, a two step IV estimation using the residuals from the system GMM estimation. Findings suggest that stocks, production, international price volatility, and governance significantly affect domestic price variability. Furthermore, improved functionality of markets and reduced transaction costs can stabilise prices. With respect to agricultural policies, public stockholding seems to be associated with less volatility, whereas trade restrictions do not enhance price stabilisation. Lastly, landlocked countries experience less variability in grain prices, while African countries have more volatile prices than countries on other continents.

Keywords

Determinants of food price volatility, public buffer stock, competitive storage, system GMM

1 Introduction

Food price volatility is one of the major concerns for policy makers and development practitioners worldwide. During the last five years international and domestic food prices spiked multiple times and remain very volatile. This development has serious consequences; especially for the poor who spend a large share of their income on food (Banerjee and Duflo, 2007). In addition, price volatility endangers macroeconomic stability and can disincentivise food production (Haile et al., 2013) which needs to be extended in order to satisfy a growing demand for grains.

The causes of international food price volatility have been extensively discussed among policy makers (FAO et al., 2011) and scholars (Wright, 2009). During the 2007/2008 crisis, numerous countries imposed trade restrictions on staple foodstuffs to prevent prices to spike in domestic markets. In consequence, international prices further increased and importing countries faced massive difficulties in acquiring necessary supply. There are numerous policy proposals in order to improve resilience of developing countries against price volatility. Among the instruments most frequently recommended are strategic grain reserves and public buffer stock schemes. Indeed, several countries reacted and implemented national food companies to engage in stockholding. This may sound surprising. Over the last 20 years governments in developing countries have been told to liberalise markets and reduce public market intervention. Food price volatility may pave the way for the reincarnation of protectionism and public interventionism. However, these policies come at high economic and fiscal costs and there is no guarantee that market interventions reduce domestic price volatility (Newbery and Stiglitz, 1981).

The objective of this study is to better understand determinants of domestic food price volatility in developing countries and to assess potential gains of policy interventions. In doing so, determinants of price volatility are theoretically discussed and their impact is empirically tested using a cross-country cross-commodity panel. The literature considers supply side factors as major price drivers. In addition to that, domestic and international prices become more and more interlinked in a globalised world. Apart from those factors, the study controls for macroeconomic, demand side, transaction cost, and policies related determinants of grain price volatility. Furthermore, the econometric model allows to account for the persistence of volatility within a dynamic panel framework.

The study differs from previous ones by the comprehensive set of countries and factors considered. Borrowing from the extensive literature on economic growth, time-invariant but observable determinants and policy variables can be estimated using system generalised methods of moments (GMM). It permits to estimate these time-invariant variables within a fixed effect model.

The remainder of the paper is structured as follows. First, a price model for storable commodities is elaborated and price volatility is defined. Then, the determinants of price volatility are presented making use of the existing literature. Section four deals with the econometric model, provides an overview about the data set, and presents the variables. Afterwards, the results are discussed. Section six concludes.

2 Storage and volatility

Market prices are the outcome of the interplay between demand and supply. By nature, the production of agricultural commodities is dependent on external circumstances as weather and the condition of the soil. This makes grain production inherently volatile across the year, whereas consumption of staple foodstuffs is more or less constant. This seasonality seems to inhibit the application of the classical supply and demand model, in this instance, when supply exceeds demand during harvest and vice versa during the non-harvest season (Helmberger and Chavas, 1996). However, commodities can be traded and stored; by this means supply is guaranteed throughout the whole year. Both trade and storage are built on the concept of excess supply and demand.

Spatial and inter-temporal arbitrageurs[1] purchase the excess production which is the difference of production and consumption (during harvest season) and supply it to the market whenever it is demanded (e.g. during non-harvest season). Thus, in the market clearing equilibrium stocks, imports, and production must equal consumption and market demand.

$$Z_t + (1-\delta)I_{t-1} - I_t + T_t = D(p) \tag{1}$$

where I_t and I_{t-1} are stock levels at t and $t-1$ and Z_t the amount produced. T_t denotes the net trade as imports minus exports. $(1-\delta)$ is the net of deterioration from inter-temporal storage. $D(p)$ denotes the linear demand function.

Storage links prices over different time periods and explains the high autocorrelation observed from actual price data (Deaton and Laroque, 1992, 1996). Abrupt and large price changes are attributed to changes in market fundamentals that shock equation (1). This is on the one hand caused by inflexible supply responses in the short run which are not capable of absorbing price shocks quickly. On the other hand demand for staple foodstuffs is highly price inelastic and price shocks do not reduce demand in order to bring equilibrium prices down.

Two different lines of thought exist to explain commodity price behaviour in a formalised model. On the one hand, the competitive storage model (Williams and Wright, 1991) that treats supply shocks as exogenous whereas demand and supply and price expectations simultaneously determine the equilibrium price. On the other hand, cob-web type models where supply is endogenously determined and prices follow cyclical fluctuations (e.g. pork cycle) as result of under- or oversupply (Mitra and Boussard, 2012). The former is more common for storable commodities. Thus, this work makes only use of the competitive storage model and links price levels to price volatility.

Following the seminal work of Deaton and Laroque (1992), the production output Z_t is stochastic but always positive with some lower and upper bound ($\underline{Z}$ and $\overline{Z}$). Storage is costly and only profitable as long as the expected price is higher than the current price plus storage costs. With rational expectations (Muth, 1961; Gustafson, 1958) a unique stationary rational expectation equilibrium (SREE) without trade implies:

$$\begin{aligned} p_t &= \beta E_t[p_{t+1}] \text{ if } I_t > 0 \\ p_t &> \beta E_t[p_{t+1}] \text{ if } I_t = 0 \end{aligned} \tag{2}$$

where p_t is the price of the commodity at time t; $\beta = \frac{1-\delta}{1+r}$ contains the interest rate r and rate of deterioration δ; $E_t[\cdot]$ refers to the expectation at time t.

Combining (1)[2] and (2) it follows that p_t is not linked to expectations about future prices with no storage undertaken. In contrast, for positive stocks, p_{t+1} also depends on storage costs and future price expectations which are a function of total available supply Q in $t+1$:

$$p_t = \beta E[f(Q_{t+1})] \tag{3}$$

Note that prices are conditional on past realisations through their inter-temporal relationship. Expectations about future prices are built from the probabilistic distribution of Z_{t+1} and can be written as:

$$E[p_{t+1}] = E[f(Q_{t+1})] = \int_{\underline{Z}}^{\overline{Z}} f(Z_{t+1} + (1-\delta)I_{t-1})g(Z_{t+1})dZ_{t+1} \tag{4}$$

[1] Afterwards traders and stockholders.
[2] without T.

where $g(Z_{t+1})$ is probability density function of Z_{t+1}.

Assuming rational expectations, forecasting errors are not systematic and zero in expectation. The dynamic model with $n \to \infty$ periods is not analytically resolvable. However, numerical simulations for i.i.d. harvests yield that it explains *stylised facts* of commodity price behaviour quite well (Cafiero et al., 2011).

A major simplification of the model is the time-constant distribution of Z without a distinction between harvest and non harvest periods. More realistic, Z is only positive for some month and zero for others. Peterson and Tomek (2005) present a monthly model where m, n, and o represent harvest months:

$$Q_t = \begin{cases} Z_t + I_{t-1} \text{ if } t = m, n, o \\ I_{t-1} \text{ if } t \neq m, n, o \end{cases} \tag{5}$$

Accordingly, Z is no more i.i.d. but its probability function rather depends on past experiences and weather conditions during planting and growing period and the particular month during the year. In consequence, prices are naturally volatile throughout the year. Both models show the strong importance of stocks to stabilise prices in compensating harvest failures.

Likewise storage, international trade affects commodity prices in an open economy. The relationship is described through the spatial price equilibrium Takayama and Judge (1971); Enke (1951); Samuelson (1952). It implies that trade (T) is profitable as long as the price margin between country i and the world market exceeds the transaction costs (k^T).

$$\begin{aligned} p_t + k^T &= e_t p_t^* \quad \text{if } T_t > 0 \\ p_t + k^T &> e_t p_t^* \quad \text{if } T_t = 0 \end{aligned} \tag{6}$$

where e_t is the exchange rate and (*) indicates the world market.

Resulting from (6), domestic prices also depend on transaction costs (shipment and trade barriers) and export prices. Incorporation of international trade in the storage model affects the model in two ways. First, similarly to storage, trade can reduce price variability (Makki et al., 1996, 2001). Secondly, storage and trade interact and equilibrium quantities of storage and trade in country A and B must be determined simultaneously (Williams and Wright, 1991). From (2) and (6) four scenarios can be derived:

Table 1: Possible scenarios from inter-temporal and spatial price models

Case 1	no current storage and no trade	$p_t = P[Z_t + (1-\delta)I_{t-1}]$
Case 2	current storage but no trade	$p_t \geq \beta E[P(Z_t + (1-\delta)I_{t-1})]$
Case 3	no current storage but trade	$p_t \geq e_t p_t^* + K^T$
Case 4	both storage and trade	$p_t \geq \max \{\beta E[P(Z_t + (1-\delta)I_{t-1})], e_t p_t^* + K^T\}$

Source: Adapted from Shively (1996).

All four cases determine the price equilibria for different market conditions. Again the model is not analytical resolvable, however, a reduced form equation for the determinants of p_t can be derived (Shively, 1996):

$$p_t = f(p_{t-i}, \beta, Z_t, I_{t-1}, D(p)_t, p_t^*, k^T, e) \tag{7}$$

where p_{t-i} represents past price realisations and D_t contains parameters of the demand function.

Heretofore the model describes the determination of price levels rather than volatility. Volatility measures the movement of a price series and is derived from the second moment of the price distribution. It can be measured in different ways:

i. changes of log returns (Gilbert and Morgan, 2010b)

ii. coefficient of variation (CV) from mean or trend (Huchet-Bourdon, 2011)

iii. as conditional probabilistic variable in generalised autoregressive conditional heteroscedasticity (GARCH) models (e.g Roache, 2010; Karali and Power, 2013).

It is generally recognised that price volatility is a stochastic process and highly variable over time (Gilbert and Morgan, 2010a). To account for these characteristics, GARCH models are widely applied especially to model financial data. Yet, among agricultural economists there is some doubt that random walk models can capture the transitory nature of shocks that are caused by fundamental determinants (Balcombe, 2009; Piot-Lepetit and M'Barek, 2011). Barrett (1995) emphasises the importance of structural variables in volatility models for agricultural commodities that are frequently omitted in GARCH models. Indeed, with the exception of the spline-GARCH model (Engle and Rangel, 2008; Karali and Power, 2013) conditional volatility models are incapable of incorporating further explanatory variables of lower data frequency.

This study focuses on domestic price volatility and its determinants. Following Balcombe (2009) the realised volatility over one marketing year is expressed as the standard deviation of the monthly log returns:[3]

$$\sigma_{p_t} = \sqrt{\frac{\sum_{m=1}^{12}(\Delta \ln(p_{mt}))}{12}} \tag{8}$$

The more and the stronger prices change, the higher the impact on σ_{p_t}. Price changes occur as soon as the variables in (7) change. In general, both positive and negative variation affects price variability. However, for some variables changes may not be linear and symmetric, especially with regard to total supply. Among the supply side variables, stocks play the major role as production does not occur for a considerable time during the year. Due to their non negativity, inventories absorb downward price changes more successfully then upward movements (Tadesse and Guttormsen, 2011). More intuitively, excess supply can be carried to future periods, whereas supply cannot be borrowed from the future in case of current deficiency. The same is illustrated in figure 1. Accordingly, price dynamics are non linear since changes in the supply of agricultural commodities lead to much higher price changes if stocks are near the minimum level (Wright, 2011). In contrast, the level of production can impact on price volatility in both directions. However, the possibility of storage dampens the negative impact.

Storage costs including deterioration and interest are unlikely to vary significantly in the short run.[4] Therefore, their impact on annual price volatility is limited. On the contrary, trade costs change rapidly and affect price levels as well as volatility. Trade costs, exchange rate, international prices, past realisation of prices, and demand side factors can be measured in volatility terms as their impacts can be assumed to

[3] $\ln \frac{p_t^A - p_{t-1}^A}{p_{t-1}^A} = \ln(p_t^A) - \ln(p_{t-1}^A)$.

[4] other than following a trend.

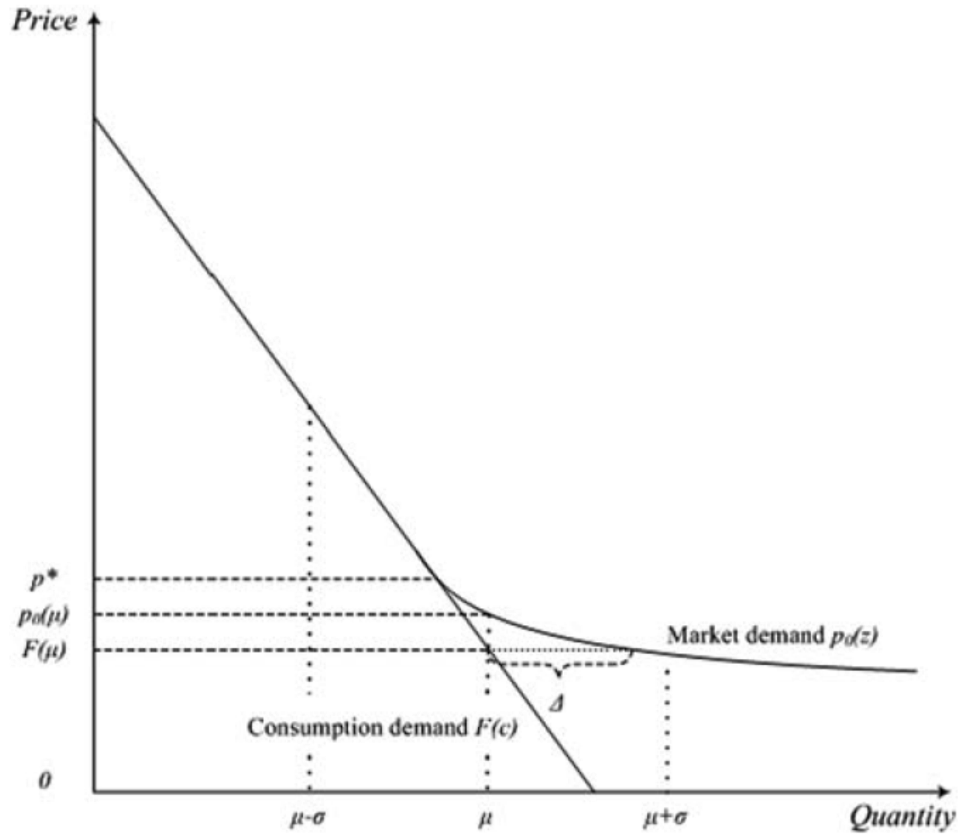

Figure 1: Non linearity of price dynamics
Source: Wright (2011)

be symmetric. In summary of the discussion, (7) can be transformed into a volatility equation:

$$\sigma_{p_t} = f(\sum \sigma_{p_{t-i}}, I_{t-1}, Z_t, \sigma D(p)_t + \sigma p_t^*, \sigma k_t^T, \sigma e_t) \tag{9}$$

3 Previous research

Apart from natural price dynamics, commodity prices have recently been declared more volatile (Roache, 2010) as prices change more rapidly and peaks reach extraordinary levels after a period a relative calmness since the 1970s. There is a large body of literature that deals with the food crisis in 2007/2008, its causes and consequences, and food price volatility in general. A broad consensus exists that a single cause has not led to the extreme price spikes (Abbott et al., 2011; Trostle, 2008).

On the one hand, exogenous factors are root causes and primary driver of food prices. On the other hand, intermediate and immediate causes are prevailing in agricultural markets and transmit the effect of primary factors into the development of prices (von Braun and Tadesse, 2012). Supply and demand shocks are considered as exogenous influences. In April 2007, a drought in Australia reduced expected harvest significantly at the time of the year when global grain supply is at the bottom. At the same time, total demand was historically high due to economic growth, increasing production of biofuel, and raising demand for futures contracts due to the financialisation of commodity markets. Agricultural markets are therefore increasingly connected to financial and energy markets (Gilbert, 2010; Serra and Gil, 2012). The debate on the role of speculation on agricultural price dynamics is far from being settled; some studies find empirical evidence of speculation affecting commodity prices or price volatility (e.g. Algieri, 2012) and some do not (e.g. Irwin et al., 2009); and the quantitative impact relative to other factors has not been assessed.

In contrast, the role of trade policies and the decline in food reserves is more clear. Both are endogenous and have not been primarily responsible for the price spike (von

Braun and Tadesse, 2012; Headey, 2010). An analysis by Martin and Anderson (2012) suggests that 30 (for wheat) and 45 (for rice) per cent of the increase in international prices can be associated to insulation policies. In addition to that, the price development was reinforced by the dependency on only few large food exporting countries and increasing demand from emerging economies as a result of prior economic growth. Lastly, prices of agricultural commodities are very sensitive to the way media is transmitting news, due to a lack of reliable information on supply and demand data (Wright, 2011).

To some extent international and domestic price determination is interlinked, albeit international prices exhibit much less seasonality than domestic prices do. As opposed to this, financialization of agricultural commodity markets does not affect domestic price development unless a significant share of total production is traded through futures contracts. Moreover, the impact of trade policies depends on the extent international prices are transmitted to domestic markets. The following paragraphs describe potential causes of domestic price development and presents related empirical literature.

Supply side factors The centrepiece of the competitive storage model is the stochasticity of production since supply shocks are generally considered as the main cause for agricultural price volatility (Dehn et al., 2005). Annual production is the product of crop yield times area. Thereby, yield variability as a consequence of weather related shocks as drought, high temperature, flood, etc. is the main cause for production shortfalls. Other than that, production variability can arise due to changes in input supply and variations in area planted (Haile et al., 2013). Apart from their own production, most countries are not isolated from supply shocks from their neighbouring countries. Shively (1996) finds this to be a factor for maize price volatility in Ghana.

As addressed in section two, stocks and imports have an unambiguously stabilising effect on prices (Miranda and Glauber, 1995; Wright and Williams, 1982). Yet, the magnitude of the stabilisation effect remains vague and may depend on several counterfactuals. Within a recently published work Serra and Gil (2012) study the price volatility in the U.S. corn market. Their findings underline the importance of stocks, especially in the short run, whereas the effect is decreasing for higher stock levels. Pietola et al. (2010) also test the relationship between price levels, price volatility, and stocks. The results suggest that stocks drive volatility but not vice versa. Generally, the importance of production, stocks, and imports depends on the characteristics of a country as closed economy, importer, or exporter. The socially optimal composition of stocks and imports is determined by total domestic supply and world prices. It is to note that - due to the substitutability of imports and stocks - great flexibility can be gained through an optimal combination of both (Gouel and Jean, 2012).

The level of stocks largely depends on the proportion of current and expected future prices. That implies a threshold that inhibits storage if prices are above this level (Ng, 1996; Chambers and Bailey, 1996). Tadesse and Guttormsen (2011) find evidence that prices exhibit larger variability above the price threshold indicating non linearities in Ethiopian price dynamics. It is apparent that price expectations matter; independent of their accuracy; for the level of stock and thus for the price formation. In consequence, distortions of the expectations (through wrong news or uncertainty) can result in large price movements.

Further, markets in developing countries are often characterised by incomplete competition (von Braun and Tadesse, 2012; Badolo, 2011). Wright and Williams (1984) show that stockholders always store less if they possess monopoly power. McLaren (1999) and Chavas (2008) provide some evidence that non competitive storage increases price volatility. Notably, in developing countries generally large amounts of the production is stored on-farm due to high transaction costs and low market integration. On-farm storage is associated with higher storage costs and marketing behaviour is different from the classical storage models. Farmers incorporate production, savings, and consumption in their marketing decision (Park, 2006). Thus, price dynamics are also largely driven by individual household decisions.

Demand side factors Higher demand obviously leads to higher prices and could influence volatility. In developing countries, population and income growth are the main drivers of domestic demand (Gilbert, 2010). Apart from growth variables, changes in taste and preferences can lead to shifts in demand from one commodity to another. However, these demand side changes are considered as rather long term and irrelevant for the kind of volatility that is subject of this study. More importantly, spillovers from other food commodities could have short to medium term effects on commodity prices. Theoretically, that is caused by substitution and income effect. Hence, a decrease in rice prices could cause higher or lower demand for other grains (e.g. Jensen and Miller, 2008). Due to the inelastic supply price changes of related food commodities could unbalance the supply-demand relationship resulting in price movements. Unlike global demand, with few exceptions (e.g. Brazil), domestic demand for food commodities is loosely linked to energy markets and therefore they are unlikely to affect domestic volatility.

Macroeconomic factors Macroeconomic factors have been identified as main drivers of global prices for agricultural commodities (Roache, 2010; Engle and Rangel, 2008; Karali and Power, 2013); most notably, interest rate, inflation, and exchange rate. It is theoretically convincing that these factors affect domestic commodity prices as well. Interest rates are an important factor for the cost of storage. The USD exchange rate plays a crucial role for countries with import dependency since most contracts in international commodity trade are settled in USD. Thus an appreciation/depreciation of the exchange rate has severe impacts on prices (Gilbert and Morgan, 2010a). Moreover, overall inflation has an impact on the price trend but also on investment profits. Lastly, in the line of Amartya Sen, overall political stability and governance effectiveness affect the functioning of markets and impact price variability.

Transaction costs The importance of transaction costs for prices of tradable commodities in food import countries is obvious (e.g. Barrett and Li, 2002). Most likely, changes in transaction costs are passed to market prices until the new price equilibrium is reached. Transportation represents the largest share. Yet, trade tariffs and transit cost can sometimes bear considerable expenses.[5] Transportation costs largely depend on global oil prices and freight rates for bulk carriers. In contrast, trade barriers and transit costs are political variables and can be adjusted if needed. In addition to that, the institutional economics literature emphasises the importance of transaction costs for the performance and functioning of markets (Rujis et al., 2004). With regard to food markets, efficiency is gained in facilitating fast and costless contacts between buyers and sellers as well as enforcing liability of contractors (Gabre-Madhin, 2001).

Agricultural policies There are three types of agricultural policies that affect commodity price behaviour. Firstly, policies related to production that have an indirect impact on market prices. Additionally, production subsidies can set (wrong) incentives for farmers, distort input allocation and may lead to inefficient supply levels for different crops. Secondly, trade policies directly affect commodity prices in the form of taxes. Export bans could stabilise domestic prices in preventing supply shortage. Lastly, price stabilisation policies that directly affect market prices. Demeke et al. (2009) provide an overview of stabilisation policies applied during the food crisis 2007/2008. Among the direct price stabilisation polices are buffer stocks, emergency reserves, price controls, and most rigorously prohibition of private trade (Wright, 2001). Apart from that, marketing boards have been provided monopoly power for grains in a number of countries throughout the 20th century (e.g. ADMARC (Malawi), FCI (India)). However, their influence was reduced during the liberalisation process within the last 30 years.

Most commonly used are buffer stocks and emergency reserves. Both imply the public participation in commodity storage. The latter involves market intervention

[5] e.g cost for storage at port.

through stock releases only when food prices spike. Unlike, buffer stocks schemes are always involved in buying and selling grain to guarantee that market prices only move within a price band. The bandwidth is restricted by publicly announced floor and ceiling prices. This intervention can stabilise commodity prices. Yet, stabilising effects depend on the choice of bandwidth (Miranda and Helmberger, 1988), institutional design of the organisation, and its fraction of the total volume traded (Rashid and Lemma, 2011). Discussions on the optimal level of public involvement in price stabilisation have a long tradition (e.g. Newbery and Stiglitz, 1982). However, a thorough policy assessment of actual stabilisation programmes is difficult since with-without comparison is not possible. An evaluation of Zambia's Food Reserve Agency (FRA) shows that its involvement reduced market prices between 14 and 36 per cent (Mason and Myers, 2013). These findings are similar to those of Jayne et al. (2008) for the National Cereals and Produce Board (NCPB) in Kenya. Public interventions come at high economic and fiscal costs and may not be always equally efficient (Rashid et al., 2007). Under certain welfare premises, *no intervention* is quite often the optimal policy (Scheinkman and Schechtman, 1983).

International prices Generally, it is believed that prices of tradable commodities are largely driven by international prices. In contrast, non-traded commodities are mainly determined by local supply and demand (Minot, 2011). Futures prices (at major commodity exchanges) and export prices (at main ports) are considered as international prices since they serve as references prices for market participants globally. The importance of international prices for domestic price volatility is insofar crucial as international prices have been extremely volatile within the recent years. On that account, international price volatility could be a major threat for domestic price stability within the coming years.

Apart from simple correlation or graphical analysis, a vast amount of literature on price transmission exists. It is influenced by recent advances in time series methods. Nowadays, most of the works apply co-integration techniques. Most of these studies concentrate on the relationship between price levels aiming at estimating an elasticity parameter that reveals by how many percent domestic prices raise if the international price increases by one percent. Intuitively, if prices transmit it is expected that volatility is transmitted as well.

Focusing on multi-country studies, it is apparent that the level of price transmission varies significantly among countries and between commodities (Minot, 2011; Greb et al., 2012). Domestic food prices in Sub-Saharan Africa tend to be less integrated than prices in Latin America and Asia (Conforti, 2004; Robles, 2011). More recently, Ianchovichina et al. (2012) analyse price behaviour in the Middle East and North Africa (MENA) countries. Their results suggest relatively high price transmission to the national food price indices that are prepared by national statistical offices to control food price inflation.[6] Notably, Ianchovichina et al. (2012) find strong evidence that price increases are transmitted faster and to a greater extent than price decreases. In a very comprehensive study Greb et al. (2012) also look at the determinants of the level of price transmission within the scope of a meta-analysis without conclusive results. Further, applying co-integration analyses, they find roughly 75 per cent (50 per cent in 6-7 month) of the change in international prices is transmitted to domestic markets.

To the knowledge of the authors, only Rapsomanikis and Mugera (2011) and Huh et al. (2012) examine price volatility transmission to developing countries. The former study finds large volatility spillovers during the phases of high international price volatility but little for the time before 2007. Huh et al. (2012) apply a panel model using food price indices rather than commodity prices. Their findings suggest a significant but small impact of international food price volatility.[7]

All in all, price transmission appears to be rather incomplete, especially for African countries. A lack of price transmission could be explained by a large portion of trans-

[6]Food price indices represent a weighted basket of different final consumption goods such as bread.
[7]from the FAO Food Price Index.

action costs and agricultural policies (Rapsomanikis, 2011). Further, asymmetries and structural breaks in the relationship may inhibit significant transmission effects.

In summary, the empirical literature shows a lot of evidence for the theory of storage presented in the previous section. Yet, with regards to policy variables such as trade measures and public price stabilisation programmes, only few studies are available. In addition to that, research with respect to developing countries is scarce, possibly due to the lack of reliable and adequate data.

4 Empirical strategy

Due to availability and structure of the data, the analysis of determinants of price volatility is based on volatility within one marketing year. In agriculture, the term marketing year is used to indicate the period from the beginning of a new harvest until the respective harvest within the next calendar year. Country and crop level information is provided by the United States Department of Agriculture (USDA).

Accordingly, volatility is formed as an annual figure calculated from monthly retail and wholesale price fluctuations. However, availability of historic monthly price data for individual commodities is limited for most developing countries. Therefore, the observation period is restricted to the time between 2000 and 2012. This leaves us with only few observations per country. On that account, the unit of analysis is crop-country-year within a panel of more than 50 countries and a maximum of twelve years per unit. Countries and crops are listed in Table 7.

4.1 Model structure

In the literature overview, it has been shown that price volatility can be attributed to multiple causes and a clear linkage between market fundamentals as well as macroeconomic variables and volatility has been established. Apart from these variables, price variability is subject to country and crop specific factors. Some of them are observable or attributable to a broader category. By their nature, some of these factors are constant over time. In addition to that, data on public policies, governance, market performance, and transaction costs is difficult to obtain, particularly for such a large dataset. In order to nevertheless include these variables, indicators need to be used. Some of them are dummies and constant over time. For this reason, the structure of the empirical model may be written as:

$$\sigma_{ijt} = \gamma X'_{ijt} + \theta I'_{ij} + u_{ijt} \tag{10}$$

where σ_{ijt} stands for the price volatility and X' and I' are vectors of time-varying and time-invariant but observable regressors. u_{ijt} is the error term.

Besides observable time-invariant determinants, variables exist that cannot be observed. The unobserved heterogeneity is owed to crop characteristics and regional or country specific demand and supply patterns. Unobserved individual heterogeneity is widely assumed to be present in cross country samples (Acemoglu et al., 2008; Huh et al., 2012). In consequence, the ordinary least squares (OLS) estimator suffers from omitted variable bias (OVB) due to unobserved heterogeneity that is correlated with the observed independent variables (Cameron and Trivedi, 2005).[8]

In contrast to the OLS estimator, the within-estimator purges out the unobserved individual fixed effects α_{ij} by subtracting its averages from (10):

[8] $E[X_{ijt}|u_{ijt}] \neq 0$.

$$\sigma_{ijt} - \overline{\sigma}_{ij} = \gamma(X'_{ijt} - \overline{X}'_{ij}) + \theta(I'_{ij} - I'_{ij}) + u_{ijt} - \overline{u}_{ij} \tag{11}$$

$$u_{ijt} = \alpha_{ij} + \epsilon_{ijt} \tag{12}$$

where α_{ij} denotes the individual fixed effect and ϵ_{ijt} is the i.i.d. error. I'_{ij} is already the average as it is independent of t.

As a result, the estimation of γ becomes consistent since $E[\dot{X}_{ijt}|\dot{u}_{ijt}] = 0$.[9] Albeit, the procedure also removes the time-invariant variables of interest (I'_{ij}) and prohibits an estimation of θ.

4.2 Dynamic panel bias and estimation of time invariant regressors

Another source of bias comes from inclusion of the lagged dependent variable into the model. Consider the dynamic version of (11):

$$\sigma_{ijt} - \overline{\sigma}_{ij} = \beta(\sigma_{ij,t-1} - \overline{\sigma}_{ij}) + \gamma(X'_{ijt} - \overline{X}'_{ij}) + \theta(I'_{ij} - I'_{ij}) + u_{ijt} - \overline{u}_{ij} \tag{13}$$

The endogeneity comes from the fact that $\sigma_{ij,t-1}$ is correlated with $u_{ij,t-1}$ but also with $\overline{u}_{ijt}$. In consequence, the regressor $\sigma_{ij,t-1} - \overline{\sigma}_{ij}$ is correlated with $u_{ijt} - \overline{u}_{ij}$ and the within-estimator becomes inconsistent unless $T \to \infty$ and the weight of $u_{ij,t-1}$ in $\overline{u}_{ijt}$ is relatively small (Nickell, 1981). In addition, $\sigma_{ij,t-1}$ may also predetermine other explanatory variables and hence they are also correlated with $\overline{u}_{ij}$ (Roodman, 2009). It can be shown that OLS and random effects estimator also yield inconsistent estimates (Cameron and Trivedi, 2005).

An alternative way in order to purge away unobserved individual effects is the first differences estimator that uses lags instead of averages:

$$\sigma_{ijt} - \sigma_{ij,t-1} = \beta(\sigma_{ij,t-1} - \sigma_{ij,t-2}) + \gamma(X'_{ijt} - X'_{ij,t-1}) + \theta(I'_{ij} - I'_{ij}) + u_{ijt} - u_{ij,t-1} \tag{14}$$

In this case $\sigma_{ij,t-2}$ can be used as an instrument for $\sigma_{ij,t-1} - \sigma_{ij,t-2}$ (Anderson and Hsiao, 1981). However, at the cost that one entire period of observations is lost.

So far, it has only been dealt with the consistent and efficient estimation of the dynamic panel and the inclusion of time-invariant variables has been neglected. For the static case, the instrumental generalised least squares (GLS) estimator by Hausman and Taylor (1981) can be used in order to estimate time-invariant regressors. The omitted variable bias is dealt with by instrumenting potentially correlated regressors with strictly exogenous ones.

Yet, the estimator may lack efficiency, for not using all available instruments. Making use of all available moment conditions, Blundell and Bond (1998) propose to estimate a system of equation including the difference-equation (14) and the corresponding level equation:

$$\sigma_{ijt} = \beta\sigma_{ij,t-1} + \gamma X'_{ijt} + \theta I'_{ij} + u_{ijt} \tag{15}$$

Hereby, the differences serve as instruments for the level equation, whereas lagged levels are instrumentalized in the difference equation (14). In consequence, their system GMM estimator allows to estimate θ without losing consistency. However, this is based on the assumption that differences which are used as instruments are not correlated with the fixed effect (α_{ij}) (Roodman, 2009). The validity of the set of instruments can be tested using Hansen or Sargan Test of overidentifying restrictions.

[9] $\dot{X}_{ijt} = X'_{ijt} - \overline{X}'_{ijt}$ and $\dot{u}_{ijt} = u_{ijt} - \overline{u}_{ijt}$

As a matter of fact, it is very likely that observed time-invariant country characteristics are correlated with the fixed effect (Hoeffler, 2002). As a result, the system GMM estimator is inconsistent. Among others, Cinyabuguma and Putterman (2011) and Kripfganz and Schwarz (2013) apply a two stage estimation approach. In this instance, only time-variant regressors are included in the first stage using either difference or system GMM. As a result of this regression, u_{ijt} is obtained containing observed and unobserved time-invariant effects as well as the normally distributed regression error ϵ_{ijt}. In the second stage, the u_{ijt} errors are regressed on the time-invariant regressors within a cross sectional regression framework:

$$u_{ijt} = \theta_1 F'_{ij} + \theta_2 f'_{ij} + \alpha_{ij} + e_{ijt} \tag{16}$$

where F_{ij} contains strictly exogenous time-invariant regressors and F_{ij} contains endogenous time-invariant regressors. Both constitute to I' from above.

Equation (16) can be estimated using two stage least squares (2SLS), where the exogenous time-invariant variables F_{ij} and the time-variant regressors from the first stage estimation serve as instruments. Kripfganz and Schwarz (2013) show that in this instance only the final observation period T can be used in order to maintain the full set of instruments.

Both difference and the system GMM potentially suffer from inconsistency as a consequence of too many instruments (Roodman, 2007). Alongside, results on overidentifying restrictions tests may be compromised. The problem can be solved empirically by reducing the number of instruments as an option of Rodman's xtabond2 in Stata 12. In this analysis, system GMM is preferable as Bond et al. (2001) show that difference GMM can lead to biased results when the dependent variable is persistent.

4.3 Determinants of interest and controls

The main contribution of this study is the comprehensive dataset that allows to include most of the variables discussed in the literature review in a single econometric model. Further, the intention is to include all developing countries with their respective staple food crops. The selection criterion is the availability of monthly retail or wholesale price data for individual staple food crops.

In general, it is attempted to design all independent variables as variable over time apart from naturally time-invariant country characteristics. Yet, data availability and frequency of data updates do not allow every determinant to be measured annually. Therefore, some indicators are measured only as a constant. It is planned to further improve the dataset from this side.

The core model contains fundamental demand and supply variables. **stocks (-)** and **low production (-)** are included in the dynamic panel regression and measure the relative level of beginning stocks and production with respect to average production levels. The latter is constructed as a dummy variable that is 1 whenever production drops by more than seven per cent. This choice is made in order to prevent the expected sign of the variable to be ambiguous as discussed by Balcombe (2009).

To account for the potential influence of international prices implied by the spatial price equilibrium, **vol int price (+)** measures international price volatility of the respective commodity over a country's marketing year. Further, **vol exchange rate (+)** represents a country's USD exchange rate volatility and captures changes in price competitiveness as result of macroeconomic changes. Note that (6) is independent of the quantity or share imported from the world market. Both volatilities are calculated using the same formula as for domestic price volatility.

As a macroeconomic determinant, the volatility of the international oil price should be included in the model. Yet, it only varies by year but not by country and crop. Therefore, the effect may not be adequately measured due to limited variation in the data. However, it is assumed that its impact is captured by the year dummies included in the regression. Lastly, **vol fpi (+)** denotes the annual volatility of the national food price index and accounts for short term demand shocks and volatility spillovers from other crops. The inclusion of both food price volatility and exchange rate volatility is justified by the fact that the real exchange rates deviate significantly from nominal exchange rates. Secondly, the respective volatilities are not as strongly linked as food price and exchange rate levels. Again, the volatility is computed using equation (8).

Domestic transaction costs and market performance are measured using a multi component index. **quality of market (-)** uses equal weights for road infrastructure (% of paved roads), economic freedom, mobile phone penetration, and existence of a commodity exchange (100 if yes, 0 if no). Mobile penetration and economic freedom are measured relative to the rate for the US. Transaction costs of international trade are considered using the Liner Shipping Connectivity Index (**LSCI (-)**) which is zero for landlocked countries.

The Herfindahl index describes the level of market concentration. The formula is given by:

$$\overline{H}_{ij} = \frac{1}{11} \sum_{t=2000}^{2010} H_{ijt} = \frac{1}{11} \sum_{t=2000}^{2010} \sum_{n=1}^{N} s_{ijnt}^2$$

with s_{ijnt} denoting the market share of exporter n to the overall imports of crop j into country i.

Bilateral trade flows for agricultural commodities are available only until 2010. Further, the trade flows reflect trading activity within calendar rather than marketing year. International commodity market are thin and importing countries can only rely on a few trading partners. Therefore, **herfindahl (+)** denotes the mean of a country's annual Herfindahl indices and is chosen as an indicator for market structure of import markets and a country's ability to switch trading partners when exports become to expensive.

political stability (-) and **governance (-)** serve as additional macroeconomic control variables. Both are available on an annual base for more recent years.

The policy variables are measured as constant over time due to limited data on annual base for most of the sample countries. **public stocks**, **free trader**, and **notoriously restrictive** are dummy variables describing public intervention in foodgrain markets. They are the result of an extensive literature survey for a smaller sample of only 30 countries. The first denotes 1 if public emergency reserves or buffer stocks exist. The latter describes how often and for how long governments impose export restrictions. In contrast, **OTRI** is a continuous variable in the range between 0 and 1 measuring the trade restrictiveness importing firms face in a country.

Further **importing**, **trade switcher**, and **autarkic** refer to a country's trade balance of commodity j, whereas autarkic characterises countries with a trade share of less than one per cent. Using that type of variables should reveal whether a particular position makes countries more vulnerable to high price volatility. **africa** and **asia** examine whether African and Asian countries are more exposed to price volatility after controlling for fundamentals and policy variables.

Table 2: Explanatory variables

Name	Description	Source
vol dom price	volatility of domestic commodity prices †	FAO GIEWS, WFP VAM, FEWS.net, national sources
L.vol dom price	lagged volatility of domestic commodity prices †	
vol int price	volatility of international export prices †	FAOSTAT
vol fpi	volatility of national food price indices †	ILO
vol exchange rate	volatility of USD exchange rates †	IMF
stocks	rel. level of beginning stocks	USDA
low production	dummy for production shortfall	USDA

Continued on next page...

... table 2 continued

Name	Description	Source
quality of market	market performance index	ITU, World Bank, Fraser Institute, own research
LSCI	Liner Shipping Connectivity Index	UNCTAD
herfindahl	Herfindahl Index for market concentration	FAOSTAT
political stability	WGI for political stability	World Bank
governance	WGI for governance	World Bank
public stocks	dummy for public storage	own research
OTRI	Overall Trade Restrictiveness Index	World Bank
free trader	free trader (country)	own research
notoriously restrictive	notoriously trade restrictive (country)	own research
africa	dummy for Africa	
asia	dummy for Asia	
importing	notorious food importer	USDA
trade switcher	(country) switches between imports and export	USDA
autarkic	autarkic economy	USDA

Source: Own illustration. †calculated using (8).

5 Results

5.1 Price volatility: a survey

Before turning to the results of the cross-sectional and dynamic panel model, Figure 2- 4 presents price volatilities by continent for the three major crops maize, rice, and wheat. Comparing the figures, maize price volatility is highest, followed by rice and wheat which have nearly the same size. Sorghum and millet are relevant only for Africa and to limited extent for Middle America and are left out from the graphs. For Africa, sorghum price variability ranks second behind maize, whereas it is highest in Middle America. Apart from differences between crops, it becomes apparent that volatility levels vary between continents. However, it is not clear whether it is driven by geographical conditions or by underlying variables which are correlated with the continent.

Lastly, the figures provide an intuition that grain price volatility has changed over time. Most remarkably, maize price variability in Africa has almost doubled. In contrast, maize price volatility remained stable for the other continents. In addition, rice price volatility has increased for all continents. These findings contribute to the ongoing debate whether volatility has really increased (Minot, 2012). Indeed, the results are different from Minot (2012) who concluded that no evidence for increasing food prices can be found. He also compares volatility between landlocked and coastal, as well as for high intervention and low intervention countries. In contrast to his study, the descriptive statistics of our dataset do not show differences with respect to these variables. Differences between Minot (2012) and this study can be explained by the larger sample used in this analysis, slightly different observation periods, and the construction of the volatility measure.

Table 3: Domestic rice price volatilities

N		Maize	Rice	Sorghum	Wheat	Millet
50	landlocked	.207	.059	.0791	.058	.075
105	coastal	.086	.051	.112	.048	.079
44	public stocks	.110	.048	.083	.053	.078
40	no public stocks	.093	.051	.101	.046	.073
21	notoriously trade restrictive	.125	.054	.101	.040	.075
40	occasionally restrictive	.081	.043	.079	.057	.071
23	free trader	.111	.051	.123	.038	.088

Source: Own illustration.

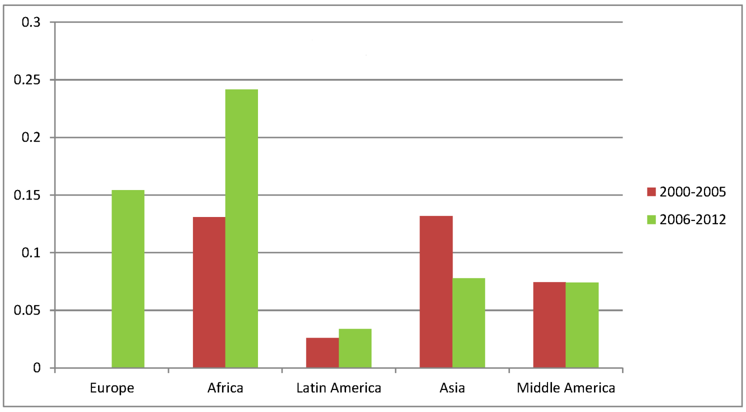

Figure 2: Maize price volatility by continent

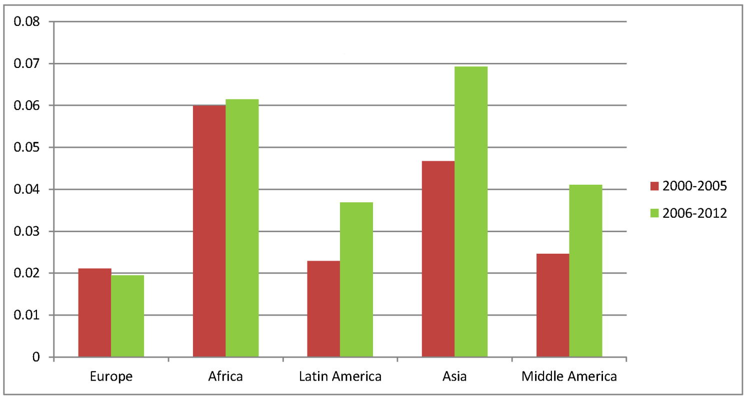

Figure 3: Rice price volatility by continent

5.2 Regression results

5.2.1 Dynamic panel

The dynamic panel regression is executed using Rodman's xtabond2 in Stata. All GMM regressions employ the two step estimator which is heteroscedasticity robust but standard errors potentially downwards biased. Therefore, Windmeijer's standard error correction is applied. Marketing year time dummies are included as suggested by

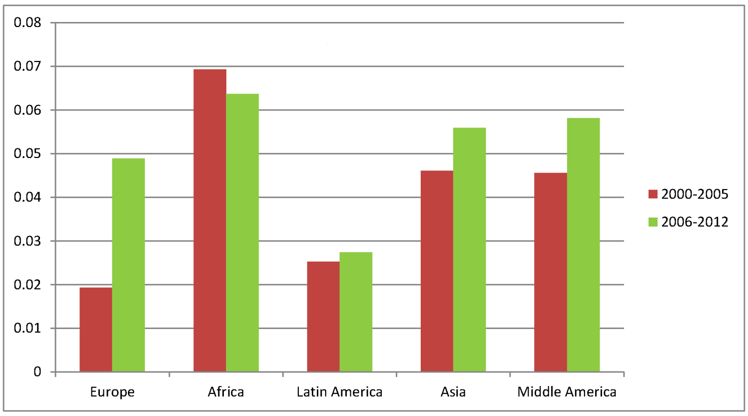

Figure 4: Wheat price volatility by continent

Roodman (2009), yet, Table 8 shows that results are not sensitive to their exclusion reported in the second column. Marketing year coefficients are not reported since they are not in particular interest of the analysis.

In each regression, the dependent variable is the logarithm of the domestic price volatility within each marketing year. In order to account for persistence, the first lag of domestic price volatility is included as an explanatory variable. Robustness checks which are not reported here confirm the choice of only one lag. The first column in Table 4 presents the OLS results. International price volatility, demand shocks, and market quality are highly significant with the right sign. In contrast, exchange rate volatility negatively affects domestic price volatility which is counter intuitive. All other variables are not significant, however, they potentially suffer from OVB and endogeneity problems from the inclusion of the lagged dependent variable. Lagged domestic volatility is indeed highly significant emphasising the persistence hypothesis.

Furthermore, the within-estimator is applied for the same model. With the exemption of the lagged volatility and exchange rate volatility, the coefficients for the significant variables are in the same range. The coefficient for **l.vol dom price** is much lower than the OLS counterpart. This difference is expected. Indeed, OLS and the within-estimator represent the upper and lower bound for system and difference GMM estimators (Hoeffler, 2002; Roodman, 2009). Additionally, a number of variables have similar coefficient estimates using OLS, within, and system GMM estimation. However, different signs for stocks and production hint at OVB and dynamic panel bias.

Column 3 and 4 show the system GMM estimation of the core models as well as the same specification estimated using difference GMM. The coefficients for the lagged dependent variable are in the expected range. Stocks and production as well as their interaction term are potentially endogenous and treated as such in the regression. Since exchange rates are driven by the domestic price level, their volatility is also treated as endogenous. Table 9 in the appendix performs robustness checks for system GMM treating those variables as predetermined and strictly exogenous. As the regression output shows, the coefficients are not subject to their treatment in the regression.

Table 4 also includes standard specification tests for dynamic panel regressions. First, the Arellano-Bond test for autocorrelation is used in order to test for the autocorrelation in levels. For both system and difference GMM the null of no autocorrelation cannot be rejected. Second, Sargan and Hansen tests for instrument exogeneity are performed. The first is not robust, whereas the second weakens with too many instruments. Following Roodman (2007), the number of GMM type instruments is collapsed and the number of instruments used is reported. Sargan and Hansen both accept the null hypothesis of instrument exogeneity. Therefore, it is assumed that the specification chosen is passing standard testing procedures.

At the first sight, difference GMM and system GMM show substantial differences with respect to point estimates and standard errors. However, in both regressions the lagged dependent variable and cross price volatility are significant, while the coefficients are very similar. In contrast to the system GMM estimation, exchange rate volatility is

Table 4: Core regression model

	OLS	FE	systemGMM	diffGMM
L.vol dom price	0.537***	0.0290	0.133**	0.121*
	(0.000)	(0.440)	(0.029)	(0.055)
vol int price	0.218***	0.206***	0.204**	0.143
	(0.006)	(0.003)	(0.015)	(0.143)
vol exchange rate	-0.0707***	0.0230	0.0667	0.107*
	(0.000)	(0.380)	(0.220)	(0.088)
stocks	-0.00164	0.00220	-0.00737***	0.000842
	(0.337)	(0.715)	(0.005)	(0.785)
lvol fpi	0.216***	0.207***	0.268***	0.202**
	(0.000)	(0.000)	(0.000)	(0.012)
low production	0.0223	0.0153	0.256**	0.241**
	(0.642)	(0.722)	(0.018)	(0.035)
stocks × low production	0.00209	-0.00316	-0.00184	-0.00367**
	(0.666)	(0.501)	(0.238)	(0.023)
LSCI	-0.000474	0.0276***	-0.00334*	0.00132
	(0.780)	(0.004)	(0.089)	(0.932)
governance	-0.0744	0.321**	-0.217**	0.310
	(0.160)	(0.045)	(0.030)	(0.297)
quality of market	-0.00362**	-0.00534	-0.00539*	-0.00429
	(0.014)	(0.431)	(0.093)	(0.787)
_cons	0.125	-1.404***	-0.501	
	(0.606)	(0.007)	(0.319)	
year dummies	yes	yes	yes	yes
N	849	849	849	723
N instruments			74	68
AR (2)			0.380	0.373
Sargan Test			0.416	0.322
Hansen Test			0.576	0.345

p-values in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

positively related to domestic price volatility. International price volatility is significant at the two per cent level only for system GMM. In the system GMM estimation, both low production and relative stocks are highly significant with the expected sign. Their interaction, however, is only significant at the 26 per cent level. In contrast, difference GMM yields significant estimates for low production and the interaction term with stocks but not for stocks individually. The result that stocks only matter for low levels of production is supported by the literature (Bobenrieth et al., 2012). Thus, both difference and system GMM find evidence for the importance of commodity stocks. Lastly, for system GMM, governance and LSCI are both significant at the ten per cent level. Quality of market is significant at the ten per cent level, however, showing higher significance levels in other specifications (see Table 8). In contrast, all of these variables are not significant using difference GMM.

In summary, differences between OLS and the within estimator compared to system and difference GMM can be observed. This provides support for the use of GMM instead of more basic estimation methods. Difference and system GMM show large similarities with respect to fundamental and volatility variables, yet, differ with respect to transaction costs, governance, and quality of markets. This may be caused by high variation between countries instead of variation over time which is detected more easily using levels than differences. In the following, the discussion of the results concentrates on the preferable estimator that is system GMM.

Generally, the system GMM results fit quite well to similar research and the theoretical model. Both Huh et al. (2012) and Balcombe (2009) find price volatility to be persistent. However, their estimates are substantially higher, likely due to the fact that this analysis incorporates a larger number of explanatory variables. The first also examine national price volatility and the impact of international prices on it. Unlike Huh et al. (2012), lags of international price volatility are not significant in any of our specifications. Apart from that, they find international volatility to be a highly significant driver of national volatilities, yet, at a smaller magnitude than in our regressions. The coefficients of international price volatility and national food price volatility can be interpreted as elasticities. Hence, on average, domestic price volatility increases by two per cent when international price volatility increases by ten. Similarly, volatility from the national food price index spills over to a slightly higher extent.

With respect to fundamental stock and production data, Huh et al. (2012) find the production index to significantly affect price volatility, while Balcombe (2009) cannot find any effect for yields. The latter explains it by their construction of the variable which is also different from the low production dummy used here. In general, variability in production or yields is considered as a main driver of price changes. Evidence comes from international (e.g von Braun and Tadesse, 2012) and country-level (e.g Shively, 1996) studies. Stocks are found to be very significant in our specifications supporting the findings of Balcombe (2009) for international markets and Serra and Gil (2012) for the US. There is no study using stocks within our type of cross-country regression. Country level analysis is often based on price data only but shows that price variability increases once stock-out prices are reached (Tadesse and Guttormsen, 2011). The low production dummy implies that volatility increases by .2 when the size of the harvest reduces significantly. On the contrary, a higher stock to production ratio reduces at domestic volatility in the area of .01.

The importance of transaction costs is empirically confirmed but no study applies such measures in a way it is done here. Lastly, governance or political stability are widely used macroeconomic variables. Yet, Huh et al. (2012) cannot find any effect on price volatility in their model. The impact of these measures on price volatility is quite large. LSCI and quality of market are measured in percentage terms. It implies an increase in ten percentage points leads to a decrease of volatility by .03 and .05, respectively. In contrast, the World Governance Indicators (WGI) are measured within a range from -2.5 to +2.5. Thus, an increase by one unit can be interpreted reasonably well resulting in a reduction of .2.

In summary, for those variables where a significant impact is found, all signs are as expected. The magnitude of the effect is similar to existing studies, if comparison is possible. In addition to that, all specification tests are passed, findings are robust throughout different specifications, and coefficient estimates are not sensitive to the treatment of potentially endogenous variables.

5.2.2 Effect of time-invariant variables

As described in the methodological section, the model for time-invariant but observable determinants is estimated in two ways. First, it is assumed that all time-invariant factors are orthogonal to the fixed effects. Thus, they can be treated as strictly exogenous in the level equation. Second, a two-step approach is taken which allows the variables to be correlated with the fixed effects. In the first step, domestic volatility is regressed on all time-variant variables and consistently estimated using system GMM. Afterwards, the regression error which contains the country-crop fixed effect and the normally distributed error term is regressed on the time-invariant variables of interest. In order to achieve a consistent estimation of step two, potentially endogenous variables are instrumented. Overidentification tests are performed and robust standard errors are employed.

Table 5 presents the results from the system GMM estimation. The dummy variables africa and landlocked are significant and unlikely to be correlated with the fixed effect. The findings suggest significantly lower volatility for landlocked countries at the one per cent level which is confirmed by the two-step estimation. The coefficient is most likely

Table 5: Time invariant factors: system GMM

	(1)	(2)	(3)	(4)
L.vol dom price	0.215***	0.158**	0.184**	0.161**
	(0.010)	(0.040)	(0.012)	(0.015)
vol int price	0.195*	0.157	0.169*	0.272***
	(0.079)	(0.127)	(0.094)	(0.003)
vol exchange rate	0.00350	-0.0118	-0.00128	-0.0240
	(0.938)	(0.749)	(0.970)	(0.199)
stocks	-0.00226	-0.00289	-0.00478***	-0.00643***
	(0.314)	(0.131)	(0.004)	(0.002)
vol fpi	0.248***	0.292***	0.360***	0.250***
	(0.007)	(0.000)	(0.000)	(0.000)
low production	0.354	0.338*	0.387**	0.167
	(0.153)	(0.062)	(0.041)	(0.206)
stocks × low production	-0.622	-0.715	-0.808	-0.00126
	(0.194)	(0.154)	(0.139)	(0.365)
governance	-0.188	-0.300**	-0.326***	-0.223*
	(0.255)	(0.021)	(0.006)	(0.052)
quality of market	0.00306	-0.000830	-0.00409	-0.00841**
	(0.611)	(0.832)	(0.286)	(0.013)
public stocks	0.0543			
	(0.660)			
landlocked	-0.278*		-0.412***	
	(0.060)		(0.004)	
herfindahl	0.485			
	(0.203)			
africa	0.651**			
	(0.034)			
notoriously restrictive		-0.0716		
		(0.595)		
asia		0.284		-0.296
		(0.403)		(0.150)
importing		-0.381**		
		(0.040)		
free trader			-0.0758	
			(0.550)	
OTRI				0.149
				(0.692)
autarkic				0.123
				(0.315)
_cons	-1.948**	-1.027*	-0.409	-0.570
	(0.046)	(0.064)	(0.493)	(0.256)
year dummies	yes	yes	yes	yes
N	478	645	645	805
N instruments	68	78	77	78

p-values in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

in the range between -.4 and -.5. This is somehow counter-intuitive but support Minot (2012), whereas coefficients cannot be compared due to different volatility measures. A possible explanation is that, naturally, landlocked countries cannot rely on food imports, as much as coastal countries can do, and thus are less exposed to international price shocks. In both regressions the Africa dummy is also highly significant with a positive sign which can be driven by the importance of maize in Africa whose prices are most volatile. On the other hand, the dummy variable for Asia does not show any significance.

Apart from the geographical variables, only importing is significant with system GMM. The negative sign implies lower price volatility in import dependent countries. Yet, this variable is likely to be endogenous to the country-crop fixed effect. In the two-step regression, no significant impact can be found.

Concentrating on the two-step regression results in Table 6, further significant explanatory variables can be identified. First, trade restriction policies seem to increase price volatility rather than decreasing it. Second, countries running public price stabilisation systems seem to have less price volatility. The former is measured by two different variables. The large coefficient for OTRI is explained by the construction of the variable which lies between one and zero. Therefore, a change of .1 is more realistic which would lead to an increase in volatility by .2. In contrast, notoriously restrictive is a dummy variable capturing the frequency and duration of export bans and quotas. Hence, trade policy restrictions seem to fail in limiting volatility transmission from international markets. Potential endogeneity between trade restrictiveness and volatility should be accounted for by the instrumental variable regression. In contrast, public participation in storage seem to be effective in combating price volatility. The large coefficient shows also strong relevance for price dynamics but supports findings from country level studies (e.g. Mason and Myers, 2013).

Table 6: Time invariant factors: two step estimates

	u_{it}	u_{it}	u_{it}
OTRI	2.037**		
	(0.044)		
importing	-0.141		
	(0.605)		
landlocked	-0.157	-0.485***	-0.421**
	(0.517)	(0.009)	(0.021)
africa	0.410***	0.448**	
	(0.005)	(0.045)	
public stocks		-0.625**	
		(0.050)	
trade switcher		0.504**	
		(0.021)	
herfindahl			0.965
			(0.173)
notoriously restrictive			0.557*
			(0.075)
asia			-2.143
			(0.361)
_cons	-0.668**	-0.145	-0.636
	(0.041)	(0.427)	(0.215)
N	72	57	42

p-values in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Further, countries which switch between importing and exporting depending on the size of the harvest do experience higher volatility than strict exporters and importers. A possible explanation is that transaction costs of international trade are higher since business relationships are impermanent due to changing trade flows. Lastly, the Herfindahl Index does not seem to affect domestic price volatility. This suggests that international markets are more or less competitive and importers are not able to set market prices.

In general, results have to be taken cautiously. First, the system GMM is based on the strong assumption of strict exogeneity of time-invariant regressors. Secondly, the two step estimates may suffer from overidentification in consequence of too many instruments (Kripfganz and Schwarz, 2013). Nevertheless, findings seem to be robust to the estimation approach and signs are as theoretically expected.

6 Conclusion

Food price volatility is a major concern for policy makers in developing countries. Recently, public intervention in food markets gained new popularity. This study investigates the impact of various determinants on domestic food price volatility. The findings are in line with empirical and theoretical studies in the area. Main results are: first, volatility in the previous period is an important factor emphasising persistence of price volatility. Second, stocks stabilise and production shortfalls destabilise domestic prices. Third, international price volatility has a significant impact on domestic price volatility. Then, functionality of markets and transaction costs impact on price volatility. Lastly, governance effectiveness as an indicator for political stability helps to stabilise prices. However, comparing the coefficients, stocks and production are less important than geographical conditions and policy variables.

The impact of international price volatility is insofar of great concern as international prices experience high volatility within recent years and could continue to impact domestic price stability significantly. Thus, one of the policy challenges will be to dampen the volatility spillover from international commodity markets.

The contribution of this study to the literature is threefold. Firstly, empirical research on food price instability is scarce, in particular with respect to developing countries. Secondly, the unique dataset includes not only fundamentals but also employs policy and transaction costs variables. Thirdly, controlling for theoretically relevant variables, the econometric model permits to test the importance of time-invariant but observable factors.

Looking at the impact of two types of public interventions in food markets, namely export restrictions and public buffer stocks, results suggest stabilising effects of the latter only. It indicates that properly designed and managed public buffer stock schemes can contribute to domestic price stability. Unlike public stocks, trade restrictiveness measured by two different indicators increases price volatility controlling for endogeneity. With respect to the size of the effect, policy variables seem to have a very large effect compared to fundamental supply data. Similarly, demand shocks and international price volatility have a great impact on domestic volatility.

All results need to be taken with caution. First, all coefficients indicate on-average effects. Thus, findings may not apply for a particular country but are only valid on average. Second, it is not realistic to assume that policies are time-invariant. Therefore, data improvement is necessary and aims at enhancing data quality and including new variables and more countries.

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Appendix

Table 7: List of countries and crops in sample

Country	Maize	Rice	Sorghum	Wheat	Millet	Country	Maize	Rice	Sorghum	Wheat	Millet
Armenia				√		Malawi	√	√			
Azerbaijan				√		Mali	√	√	√		√
Bangladesh		√		√		Mauritania	√	√	√	√	
Benin	√	√	√			Mexico	√	√			
Brazil		√		√		Moldova	√			√	
Burkina Faso	√	√	√		√	Mozambique	√	√			
Burundi	√		√			Myanmar		√			
Cambodia		√				Namibia	√				
Cameroon	√	√		√		Nepal		√		√	
Chad	√	√	√		√	Nicaragua	√	√			
China		√		√		Niger		√	√	√	√
Columbia	√	√				Nigeria	√	√	√	√	
Costa Rica	√	√				Pakistan		√		√	
Cote d'Ivoire	√	√				Panama	√	√			
Dominican Republic	√	√				Peru	√	√		√	
El Salvador				√		Philippines	√	√			
Ethiopia	√		√	√	√	Russia		√		√	
Gabon				√		Rwanda	√	√			
Georgia				√		Senegal	√	√	√		√
Ghana	√	√	√		√	Sri Lanka		√			
Guatemala	√	√		√		Tanzania	√	√	√		
Haiti	√	√	√	√		Togo	√	√	√		
India		√		√		Tunisia				√	
Indonesia	√					Uganda	√		√		√
Kenya	√		√	√	√	Uruguay		√		√	
Kyrgyzstan				√		Zambia	√	√		√	
Madagascar		√									

Source: Own illustration.

Table 8: Core model: different specifications

	(1)	(2)	(3)	(4)
L.vol dom price	0.133**	0.0862	0.121**	0.120**
	(0.029)	(0.112)	(0.038)	(0.037)
vol int price	0.204**	0.221***	0.206***	0.170**
	(0.015)	(0.000)	(0.010)	(0.048)
vol exchange rate	0.0667	-0.0313	-0.0261*	-0.0403**
	(0.220)	(0.100)	(0.090)	(0.039)
stocks	-0.00737***	-0.00737***	-0.00644**	-0.00717***
	(0.005)	(0.002)	(0.019)	(0.002)
vol fpi	0.268***	0.330***	0.347***	0.323***
	(0.000)	(0.000)	(0.000)	(0.000)
low production	0.256**	0.194*	0.202**	0.189**
	(0.018)	(0.090)	(0.040)	(0.049)
stocks × low production	-0.00184	-0.00119	-0.00151	-0.00243*
	(0.238)	(0.455)	(0.241)	(0.096)
LSCI	-0.00334*	-0.00278		-0.00422**
	(0.089)	(0.240)		(0.036)
governance	-0.217**	-0.181*	-0.218**	
	(0.030)	(0.069)	(0.024)	
quality of market	-0.00539*	-0.00744***	-0.00694**	-0.00960***
	(0.093)	(0.008)	(0.027)	(0.001)
political stability				-0.0711
				(0.192)
_cons	-0.501	-0.653	-0.555	-0.515
	(0.319)	(0.122)	(0.234)	(0.230)
year dummies	yes	no	yes	yes
N	849	849	932	723
N instruments	74	75	76	75
AR (2)	0.380	0.241	0.667	0.542
Sargan Test	0.416	0.016	0.224	0.0.312
Hansen Test	0.576	0.258	0.536	0.693

p-values in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 9: Core model: treatment of variables

	(1)	(2)	(3)
L.vol dom price	0.133**	0.164**	0.153**
	(0.029)	(0.023)	(0.021)
vol int price	0.204**	0.236**	0.153**
	(0.015)	(0.011)	(0.045)
vol exchange rate	0.0667	0.0550	-0.0314*
	(0.220)	(0.206)	(0.093)
stocks	-0.00737***	-0.00164	-0.00247
	(0.005)	(0.638)	(0.486)
vol fpi	0.268***	0.263***	0.293***
	(0.000)	(0.000)	(0.000)
low production	0.256**	0.0715	0.0295
	(0.018)	(0.106)	(0.445)
stocks × low production	-0.00184	0.00362	0.00172
	(0.238)	(0.158)	(0.359)
LSCI	-0.00334*	-0.00276	-0.00226
	(0.089)	(0.187)	(0.339)
governance	-0.217**	-0.214**	-0.156*
	(0.030)	(0.027)	(0.079)
quality of market	-0.00539*	-0.00569*	-0.00714**
	(0.093)	(0.071)	(0.014)
_cons	-0.501	-0.392	-0.735
	(0.319)	(0.400)	(0.106)
year dummies	yes	yes	yes
N	849	849	849
N instruments	74	78	30
AR (2)	0.380	0.547	0.610
Sargan Test	0.416	0.268	0.749
Hansen Test	0.576	0.645	0.844

p-values in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; Note in (1) stocks, low production, vol exchange rate, and stocks × low production are treated as endogenous, in (2) they are predetermined and strictly exogenous in (3).