Determinants of food price volatility in developing countries: the role of trade and storage policies

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Starting point of research:

- Research focus on international prices: financialization (Tadesse et al., 2013) and energy market spill-overs (Serra and Gil, 2012)
- Transmission of international price to domestic markets (Kalkuhl, 2014; Baquedano and Liefert, 2014)
- Little attention given to causes of *domestic* price volatility in developing countries, magnitude of internal and external drivers

Policy debates on

- Trade policy (self-sufficiency, regional trade cooperation)
- Stocks (buffer vs. emergency reserves)
- Infrastructure, transaction costs and information

Trade policy reactions

- Major exporting countries insulate their domestic markets (Martin and Anderson, 2012)
- Local/occasional exporters also use export restrictions to control national supply (Porteous, 2012)
- Negative externalities of trade policies on food deficient countries

WTO as solution?

- Bali Meeting with special emphasize on ad hoc restrictions, but with exemptions
- Empirics do not show impact of WTO on trade (predictability) (Rose, 2004, 2005)
- In contrast, RTAs seem to be associated with higher commitment (Mansfield and Reinhardt, 2008; Cadot et al., 2009)

What is price volatility?

Different components of price dynamics important:

- Price trend (long-term price level)
- Price change (log returns, $r_t = log(p_t) - log(p_{t-1})$)
- **Price volatility** (variability of prices around the trend SD(r_t))

How to measure volatility:

- Directionless price variability; extent of short-term price fluctuations
- Intention to capture realized price movements rather than current market uncertainty (SD(r_t) vs. GARCH)
- Annual volatility (standard deviation of 12 monthly price returns per country and crop)

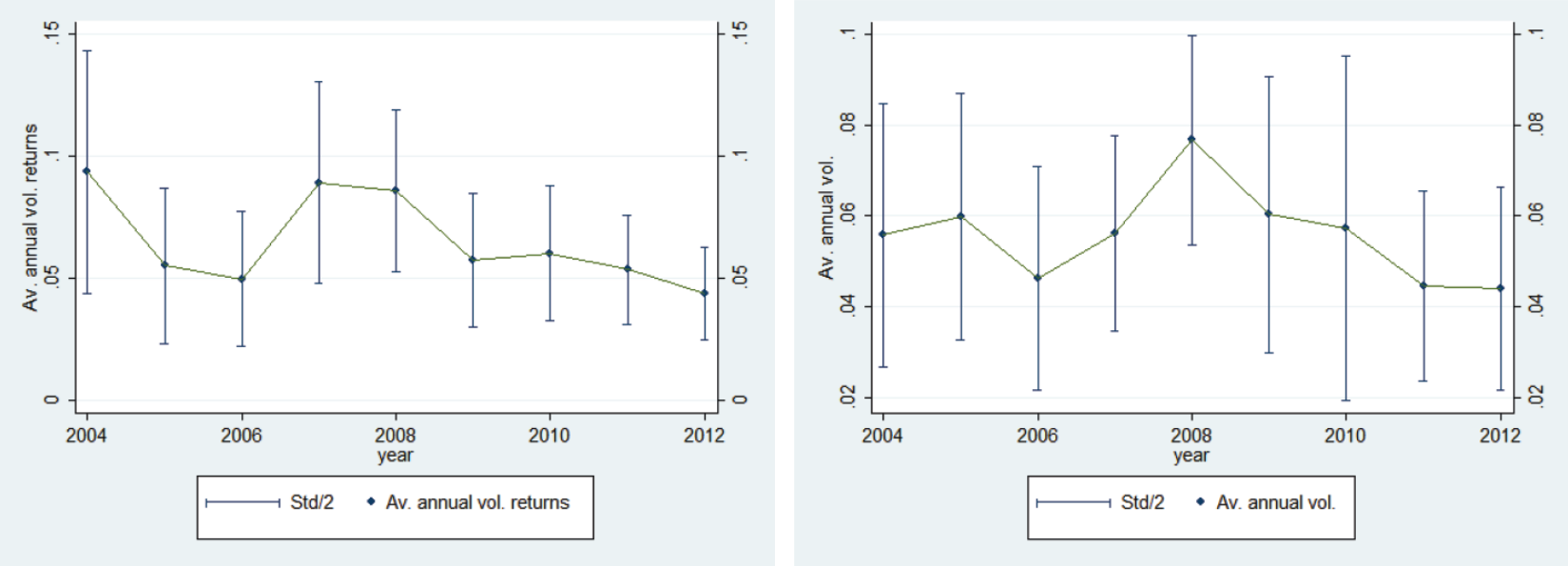

Figure: Volatility of wheat (left) and rice (right) prices in developing countries. Source: Kornher (2015).

- During international food crises in 2007/2008, volatility increased in many countries but declined continuously thereafter
- Large differences in volatility between countries

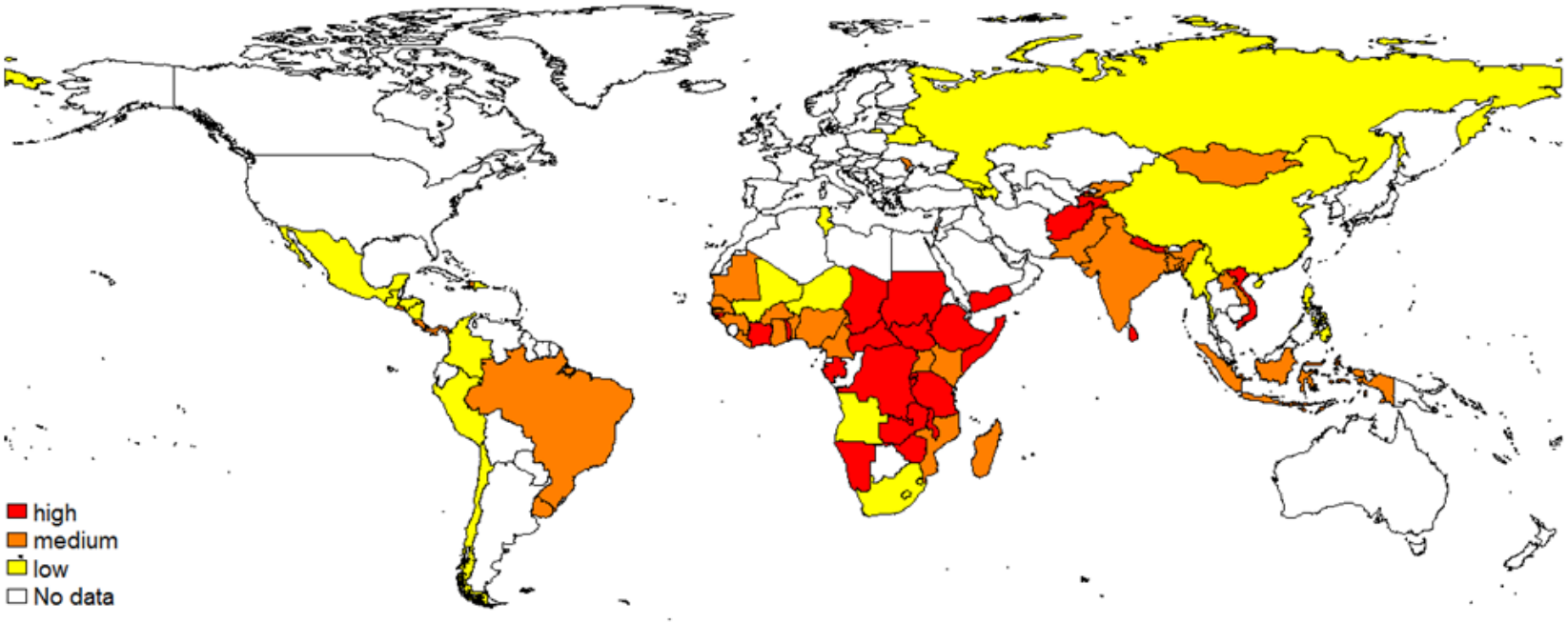

Figure: Volatility of major staple prices in developing countries. Source: Kornher and Kalkuhl (2015).

Major questions:

- What determines volatility in developing countries?
- How strong are volatility spillovers from international markets?
- Which policies can effectively reduce volatility?

Approach:

- Economic theory on trade and storage
- Dynamic panel regression on price data

Existing studies

Time-series models

- Focus on first-moment: price transmission, co-integration
- Second-moment: volatility transmission (Rapsomanikis, 2011)
- Cannot link volatility with underlying fundamental factors and policies

Panel models

- Usually not dynamic panel models (e.g. Pierre et al., 2014)
- Role of trade and storage policies neglected

Spatial trade equilibrium approach links domestic prices p_t^D to international prices p_t^G and transaction costs for importing or exporting goods, τ_t, via the arbitrage condition (Samuelson, 1952; Fackler and Goodwin, 2001):

$$p_t^D = \begin{cases} p_t^G + \tau_t & \text{if } D^{-1}(X_t, Y_t) \geq p_t^G + \tau_t \quad \textit{(import regime)} \\ p_t^G - \tau_t & \text{if } D^{-1}(X_t, Y_t) \leq p_t^G - \tau_t \quad \textit{(export regime)} \\ D^{-1}(X_t, Y_t) & \text{else} \quad \textit{(no trade)} \end{cases} \tag{1}$$

Resulting volatility for the trade regime is:

$$Var(p_t^D) = Var(p_t^G + \delta\tau_t^{pol}) = Var(p_t^G) + Var(\tau_t^{pol}) + 2\delta Cov(p_t^G, \tau_t^{pol}) \tag{2}$$

where $\delta = 1$ in case of the import regime and $\delta = -1$ for the export regime.

In the non-trade regime, domestic price volatility is determined through domestic supply and demand fundamentals as well as preferences:

$$Var(p_t^D) = Var(D^{-1}(X_t, Y_t)) \tag{3}$$

Assuming a linear inverse demand function in consumption X_t and income Y_t, we have $D^{-1}(X_t, Y_t) = A - BX_t + CY_t$ with $B, C > 0$ gives:

$$Var(p_t^D) = B^2 Var(X_t) + C^2 Var(Y_t) - 2BC\ Cov(X_t, Y_t) \tag{4}$$

Variance of supply, $Var(X_t)$, is in turn affected by production variability and (anticyclical) stock releases.

Analysis of supply variability $Var(X_t)$ in the non-trade regime in two ways:

1. Inter-annual storage using a linear storage rule (approximation of the competitive-storage model): $S_{t+1} = \gamma(Q_t + S_t)$
2. Intra-annual storage using inter-temporal arbitrage of stock-holders

In both cases, $Var(X_t)$ and $CV(X_t)$ decreases in the (mean) level of stocks.

So far, analyses for either trade ($T \neq 0$) or no-trade ($T = 0$) regime. If regime switching occurs within the observation period, the variance of domestic prices with regime switch is

$$Var(p_t^D) = \text{Prob}[T \neq 0] Var[p_t^G + \delta\tau_t | T \neq 0] + (1 - \text{Prob}[T \neq 0]) Var[D^{-1}(X_t, Y_t) | T = 0] \quad (5)$$

In general, transaction costs can increase or decrease volatility

- high transaction costs τ increase the probability of the no-trade regime
- if $Var(D^{-1}(X_t, Y_t))$ is very low which, high transaction costs reduce domestic volatility
- domestic volatility in most cases higher than international vol. (except for countries with large storage programs and low production shocks, e.g. India, China)

Dynamic panel model:

$$\text{Vol}_{ijt} = \text{Vol}_{ij,t-1} + X_{ijt} + C_{jt} + F_{it} + u_{ij} + \epsilon_{ijt} \tag{6}$$

Endogeneity:

- Unobserved individual heterogeneity is correlated with u_{ij} (fixed effect) (e.g. Wooldridge, 2002)
- Dynamic panel bias (Nickell, 1981)

Strategy:

- Dynamic panel with system-GMM (Blundell and Bond, 1998)
- Estimation: STATA 13 with xtabond2
- Collapse number of instruments

Data and variables of interest

Table: Description of variables

Name	Description	Source
Dependent variable		
vol dom price	volatility of domestic commodity prices †	ZEF Commodity
L.vol dom price	lagged volatility of domestic commodity prices †	Price Database
Anti-cyclical trade policies		
insulation	export restrictions by home country	UN Comtrade
int exp res.	export restrictions by main trading partners	UN Comtrade
reg trade	share of trade with RTA partners	UN Comtrade
Storage policies		
stocks	annual beginning stock-to-use ratio	FAO CBS
high intervention	dummy equals 1 if country *i* runs influential public stockholding	desk research
Controls		
vol int price	weighed international export prices †	IGC
vol exchange rate	LCU/USD exchange rate †	IMF
production	relative annual production	FAO CBS
M1	average annual growth rate in money supply	WDI
WGI	Kaufmann's World Governance Indicator	WGI
transaction costs	measure for market performance	ITU, WDI, Fraser Institute
Country type		
importer	dummy equals 1 if country *i* is an importer of commodity *j*	FAO GIEWS
exporter	dummy equals 1 if country *i* is an exporter of commodity *j*	FAO GIEWS
non-importer	dummy equals 1 if country *i* is not an importer of commodity *j*	FAO GIEWS
trade switcher	dummy equals 1 if country *i* is neither importer nor exporter	FAO GIEWS

Note: †Measured as standard deviation of log returns.

Trade variables

Anti-cyclical insulation of country i is measured by the deviation of exports from average exports:

$$\text{insulation}_{ijt} = -\frac{\text{Exp}_{ijt} - \widetilde{\text{Exp}}_{ij,2000-2013}}{\widetilde{\text{Exp}}_{ij,2000-2013}}$$

The export restrictions of trade partners faced by country i is measured by the deviation of imports from the five biggest trade partners from the long-term average:

$$\text{int exp res}_{ijt} = -\frac{\sum_1^5 \text{Imp}_{ijt} - \sum_1^5 \widetilde{\text{Imp}}_{ij,2000-2013}}{\sum_1^5 \widetilde{\text{Imp}}_{ij,2000-2013}}$$

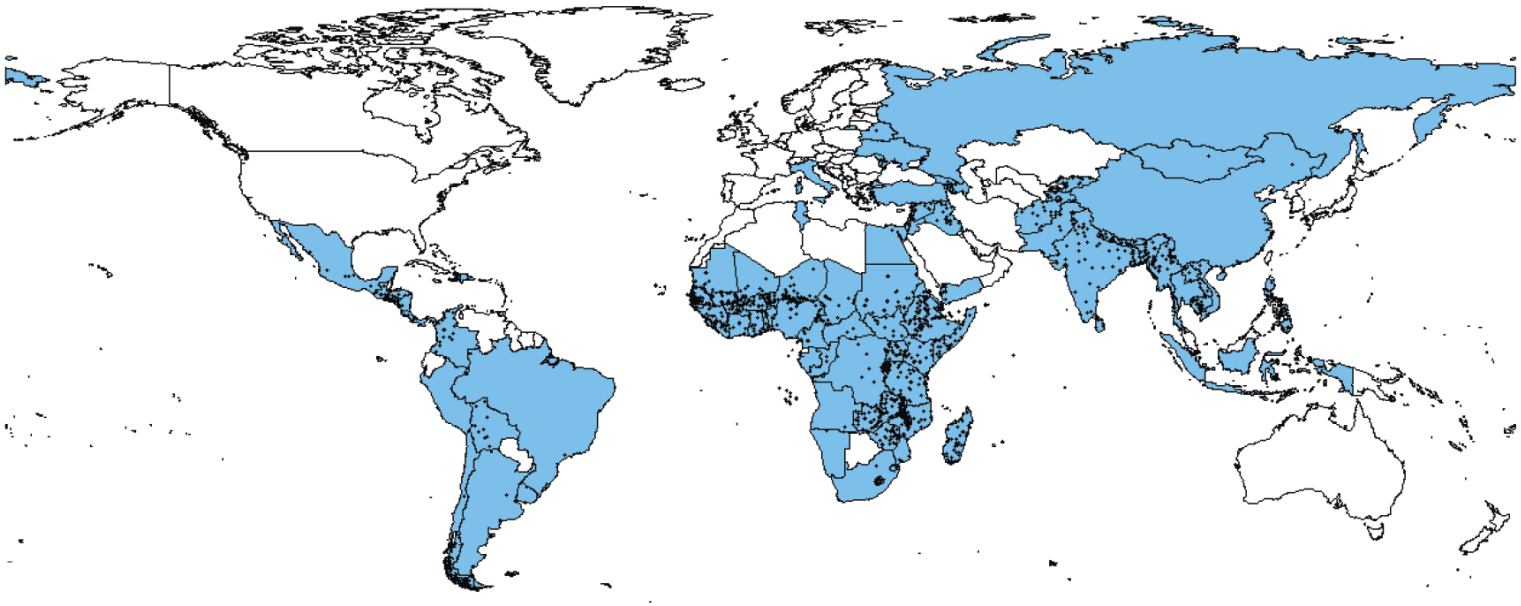

Figure: Country and market coverage of ZEF Price Database

Monthly national average retail prices from FAO GIEWS, FEWS.NET, WFP VAM and national sources for 2000-2012 with 70 countries (maize, rice, wheat, sorghum, millet).

Table: System GMM results

	(1)	(2)	(3)	(4)
L.vol dom price	0.262***	0.357***	0.355***	0.328***
	(5.17)	(6.35)	(6.19)	(6.30)
vol int price	0.291***	0.280***	0.271***	0.354***
	(6.18)	(5.93)	(5.84)	(6.83)
production	-0.0757	-0.202**	-0.176*	-0.0867
	(-1.03)	(-2.20)	(-1.89)	(-1.00)
stocks	-1.200	-2.544***	-2.575***	-1.326*
	(-1.65)	(-3.66)	(-3.56)	(-1.92)
insulation	-0.417**	-0.402*	-0.409*	
	(-2.10)	(-1.66)	(-1.81)	
int export res.	0.0566	0.240*	0.238*	
	(0.41)	(1.70)	(1.70)	
reg trade	-0.858***	-0.880***	-0.926***	
	(-3.94)	(-3.66)	(-3.66)	
M1	0.141	0.327*	0.302*	0.305
	(0.61)	(1.78)	(1.88)	(1.55)
vol exchange rate	0.0169	0.0301	0.0380	0.0397
	(0.54)	(1.14)	(1.59)	(1.23)
transaction costs	0.956***			1.23***
	(2.77)			(3.74)
WGI	0.115	0.0617		-0.0104
	(1.18)	(0.61)		(-0.14)
N	996	1270	1323	1020
N groups	140	155	157	144
N instruments	67	72	72	46
AR(2)	0.397	0.994	0.828	0.736
Sargan Test	0.171	0.015	0.388	0.000
Hansen Test	0.664	0.428	0.570	0.022
Diff.Sargan(gmm)	0.792	0.601	0.124	0.164

t statistics in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; Note: stocks, reg trade, and insulation are treated as endogenous, production is considered to be predetermined. Regressions use orthogonal deviations instead of first differences as instruments. Years are included as exogenous instruments.

Table: Relative importance of explanatory variables

	short term		long term	
	min	max	min	max
vol int price	17%	22%	25%	32%
production	-2%	-7%	-4%	-10%
stocks	-22%	-48%	-33%	-70%
insulation	-14%	-15%	-21%	-22%
int export res.	1%	4%	1%	5%
reg trade	-35%	-38%	-51%	-55%
M1	2%	5%	3%	7%
transaction costs	17%	22%	25%	32%

Note: The autoregressive term is averaged across the four specifications which yields $\beta = 0.3135$. Min and max represent minimum and maximum value of specifications shown before.

Table: Regression results by trade regime

	importer		non-importer		trade switcher	
	(1)	(2)	(3)	(4)	(5)	(6)
L.vol dom price	0.244**	0.340***	0.215***	0.352***	0.232***	0.386***
	(2.47)	(3.00)	(3.60)	(4.97)	(3.54)	(5.59)
vol int price	0.437***	0.420***	0.268***	0.271***	0.261***	0.270***
	(4.43)	(4.91)	(6.72)	(5.50)	(4.45)	(4.81)
production	-0.0817	-0.113	0.0529	-0.0805	0.0203	-0.0269
	(-1.00)	(-1.27)	(0.43)	(-0.65)	(0.11)	(-0.20)
stocks	-2.091	-3.497**	-0.623*	-1.530***	-0.832	-1.599**
	(-1.38)	(-2.49)	(-1.78)	(-3.31)	(-0.76)	(-2.61)
insulation			-0.413**	-0.370*	-0.393*	-0.459*
			(-2.24)	(-1.97)	(-1.70)	(-1.95)
int expo res.	-0.213	-0.0286			-0.105	0.0475
	(-0.37)	(-0.06)			(-0.83)	(0.29)
reg trade	-0.763***	-0.713*	-0.797***	-0.631***	-0.503***	-0.737***
	(-3.09)	(-1.87)	(-4.41)	(-2.68)	(-2.86)	(-3.08)
M1	0.421	0.504	-0.249	0.0367	0.108	0.145
	(1.10)	(1.46)	(-1.11)	(0.19)	(0.35)	(0.77)
vol exchange r.	0.000890	0.0129	0.0571*	0.0504	0.0588	0.0340
	(0.02)	(0.38)	(1.95)	(1.50)	(1.52)	(1.17)
transaction c.	0.844*		0.978***		1.44***	
	(1.75)		(3.42)		(3.30)	
WGI	-0.0973	-0.297	0.224**	0.183*	0.0833	0.104
	(-0.47)	(-1.43)	(2.17)	(1.75)	(0.70)	(0.84)
N	429	561	567	709	420	533
N groups	65	73	75	82	55	81
N instruments	57	61	66	71	67	72
AR (2)	0.346	0.061	0.091	0.178	0.149	0.224
Sargan Test	0.139	0.091	0.082	0.003	0.364	0.001
Hansen Test	0.364	0.201	0.724	0.428	0.894	0.837
Diff.Sargan(gmm)	0.797	0.610	0.939	0.746	0.979	0.990

t statistics in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; Note: stocks, reg trade, and insulation are treated as endogenous, production is considered to be predetermined. Regressions use orthogonal deviations instead of first differences as instruments. Years are included as exogenous instruments.

Table: Regression by level of public intervention

	low intervention		high intervention	
	(1)	(2)	(3)	(4)
L.vol dom price	0.228***	0.370***	0.356***	0.439***
	(3.29)	(4.97)	(3.35)	(4.17)
vol int price	0.351***	0.293***	0.281***	0.283***
	(4.78)	(4.12)	(6.95)	(3.88)
production	-0.0712	-0.137	0.0144	0.0159
	(-1.16)	(-1.43)	(0.08)	(0.09)
stocks	-0.781	-1.982**	-0.556	-1.252*
	(-1.31)	(-2.42)	(-0.84)	(-1.68)
insulation	-0.620***	-0.526*	-0.217	-0.266
	(-2.66)	(-1.88)	(-1.41)	(-1.16)
int exp res	0.146	0.338*	-0.235	-0.00492
	(0.74)	(1.95)	(-0.86)	(-0.01)
reg trade	-0.741***	-1.049***	-0.639**	-0.607**
	(-3.18)	(-5.04)	(-2.03)	(-2.30)
M1	0.354	0.449**	-1.14*	-0.224
	(1.39)	(2.15)	(-1.72)	(-0.71)
vol exchange rate	0.0257	0.0309	0.00479	0.0124
	(0.59)	(0.80)	(0.16)	(0.26)
transaction costs	1.19***		0.723**	
	(3.04)		(2.64)	
WGI	0.00500	-0.0178	0.210	0.224
	(0.04)	(-0.17)	(1.32)	(0.89)
N	673	876	323	394
N groups	75	82	55	61
N instruments	66	71	67	72
AR(2)	0.091	0.178	0.149	0.224
Sargan Test	0.082	0.003	0.364	0.001
Hansen Test	0.724	0.428	0.894	0.897
Diff.Sargan(gmm)	0.939	0.746	0.977	0.990

t statistics in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; Note: stocks, reg trade, and insulation are treated as endogenous, production is considered to be predetermined. Regressions use orthogonal deviations instead of first differences as instruments. Years are included as exogenous instruments.

Further issues

Explaining cross-country differences in volatility

- Because of fixed-effect like estimation, only changes over time (within country) are considered
- Possibility to include time-invariant variables in panel model (must be uncorrelated with fixed effect)

Two step IV estimation (Cinyabuguma and Putterman, 2011)

- Regressing residuals on time-invariant country characteristics (high intervention)
- Instruments: per capita gdp, financial freedom, share of rural population
- No evidence for lower volatility in high intervention countries

Some general findings:

- Volatility spill-overs are main driver of price volatility
- Stocks can reduce reduce domestic volatility
- Transaction costs due to poor infrastructure and institutional quality - most relevant for countries hardly involved in trade
- Production and demand shocks only of little importance - even less in countries with large stabilization programs

The role of trade:

- Regional trade integration helps to reduce volatility for all countries
- Importers are more affected by volatility transmission
- Insulation policy works for major exporters and trade switchers

Be careful with policy implications as costs and benefits of policies not included

- Large stocks involve high fiscal costs
- Poor management of stocks and discretionary trade policies create unpredictability for market agents
- Infrastructure and transaction costs have large positive side-effects (beyond volatility reduction)

The role of trade policies:

- Volatility transmission (and market integration) is not a 'bad' thing - it leads to lower domestic volatility in many cases
- Regional trade agreements promising third way between autarky and non-reliable global markets

Thank you very much for your attention!
Comments? Questions? Suggestions?

For more information:
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http://www.zef.de/volatility.html

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International food price movement since 2000

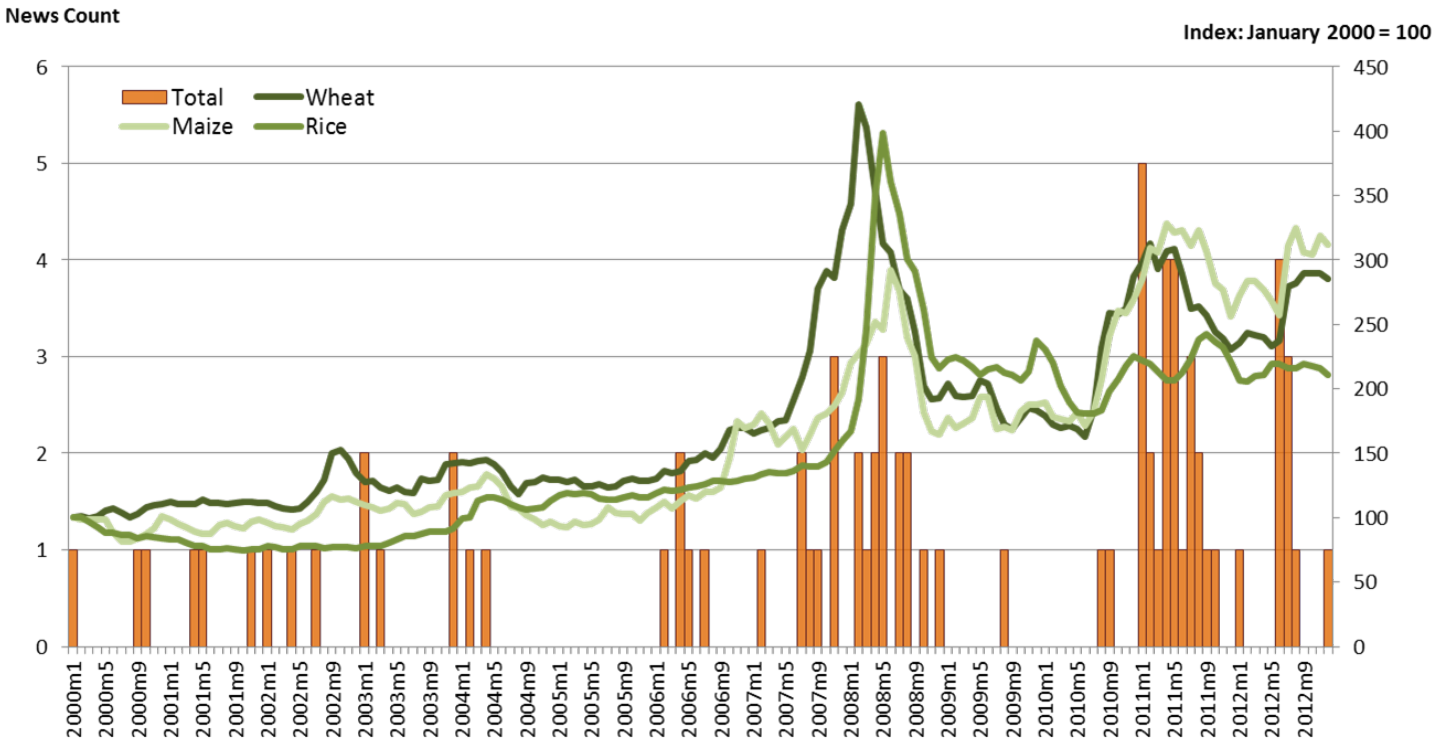

Figure: Number of food-related riots in Africa. Source: Social conflict in Africa Database (SCAD), International Grains Council (IGC).

A simple approximation of (annual) ending stocks is a linear stocking rule in domestic supply $X_t = Q_t + S_t$ with:

$$S_{t+1} = \gamma(Q_t + S_t)$$

with $0 \leq \gamma < 1$ the propensity to store.

Proposition

Given a linear storage rule for the annual ending stocks and Q_t i.i.d., the variance of inter-annual domestic supply is in the long-run

$$Var(X_t) = \psi(\varsigma) Var(Q)$$

with $\varsigma = E[S_t]/E[Q_t]$ the mean stock-to-use ratio and

$$\psi(\cdot) > 0, \psi'(\cdot) < 0$$

a decreasing function in ς. The coefficient of variation of inter-annual domestic supply decreases in mean stock-to-use ratio ς as well.

For seasonal price variability, let even indices $2t$ represent harvest periods at year t and odd indices $2t+1$ lean periods at year t.
Intra-annual storage ΔS_{2t} smooths consumption between harvest and lean season according to

$$X_{2t} = Q_{2t} - \Delta S_{2t} \tag{7}$$

$$X_{2t+1} = \Delta S_{2t} \tag{8}$$

The fundamental behavioral equation for understanding seasonal price variability is the inter-temporal arbitrage equation

$$p_{2t} = \frac{1}{1+r} E[p_{2t+1}] \tag{9}$$

We measure seasonal price variability as sample-variance over the two prices at harvesting and lean season, thus

$$V_{2t} := (p_{2t} - \bar{p}_{2t})^2 + (p_{2t+1} - \bar{p}_{2t})^2 = \frac{1}{2}(p_{2t} - p_{2t+1})^2 \qquad (10)$$

with $\bar{p}_{2t}$ the intra-annual mean price $\bar{p}_{2t} := (p_{2t} + p_{2t+1})/2$ prevailing at year t. Normalizing the sample variance by the mean price gives the coefficient of variation

$$CV_{2t} := \frac{\sqrt{V_{2t}}}{\bar{p}_{2t}} \qquad (11)$$

Proposition

Under the absence of intra-annual income shocks, the following holds:

i *the coefficient of seasonal price variation is* $CV_{2t} = \frac{r}{2+r}$;

ii *the coefficient of seasonal price variation increases in storage costs* r;

iii *the coefficient of seasonal price variation decreases in intra-annual storage levels* ΔS_{2t}.

Parameter in theoretical model	Impact on Variance	Impact on Coefficient of Variation	Associated variable in regression
Mean transaction costs			transaction costs, WGI
Permanent importer	0	−	
Permanent exporter	0	+	
Trade switcher...			
...with low domestic volatility †	−		
...with high domestic volatility †	+		
No-trader	0	0	
International volatility			vol int price
Permanent importer	+	+	
Permanent exporter	+	++	
No-trader	0	0	
Stock-to-use ratio			stocks, high intervention
Permanent importer or exporter	0	0	
No-trader	−	−	
Anticyclical domestic trade policy			
Permanent importer	−	−	
Permanent exporter	−	−	insulation
No-trader	0	0	
Anticyclical trade policy of trade partners			reg trade
Permanent importer	+	+	int exp res.
Permanent exporter	+	+	
No-trader	0	0	
Domestic income shocks			M1, vol exchange rate
Permanent importer or exporter	0	0	
No-trader	+		
Domestic production shocks			production
Permanent importer or exporter	0	0	
No-trader	+		

Policy responses to volatility

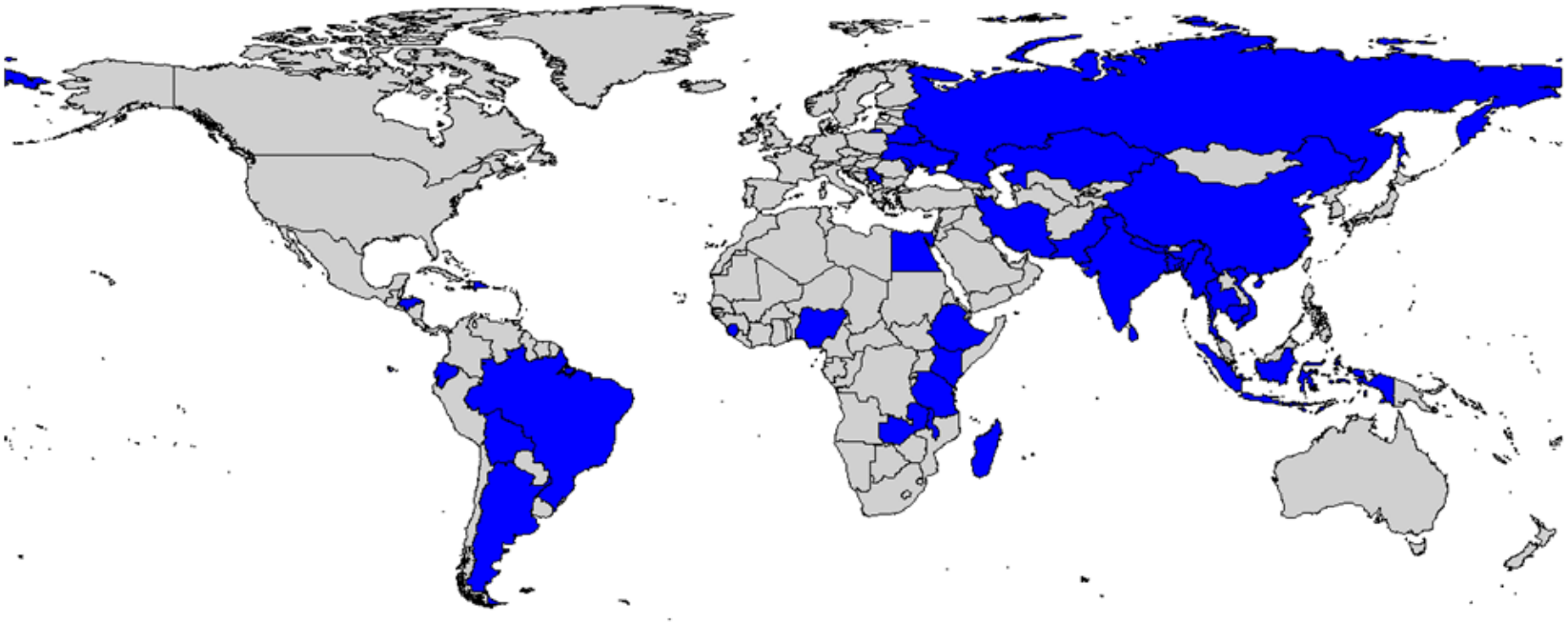

Figure: Countries applying export restrictions (2007-2012). Source: World Bank Food Policy Monitor (2014).

Table: Number of groups in sample

	maize	rice	sorghum	wheat	millet	Total
Africa	26	29	17	16	11	99
Asia	2	19	-	16	-	37
Latin America	14	14	2	9	-	39
Europe	1	1	-	2	-	4
landlocked	14	17	7	15	6	59
importer	19	38	2	33	0	92
exporter	6	7	3	3	2	21
non-importer	24	25	17	10	11	87
trade switcher	18	18	14	7	9	66
high intervention	7	19	4	13	4	47
All	43	63	19	43	11	179

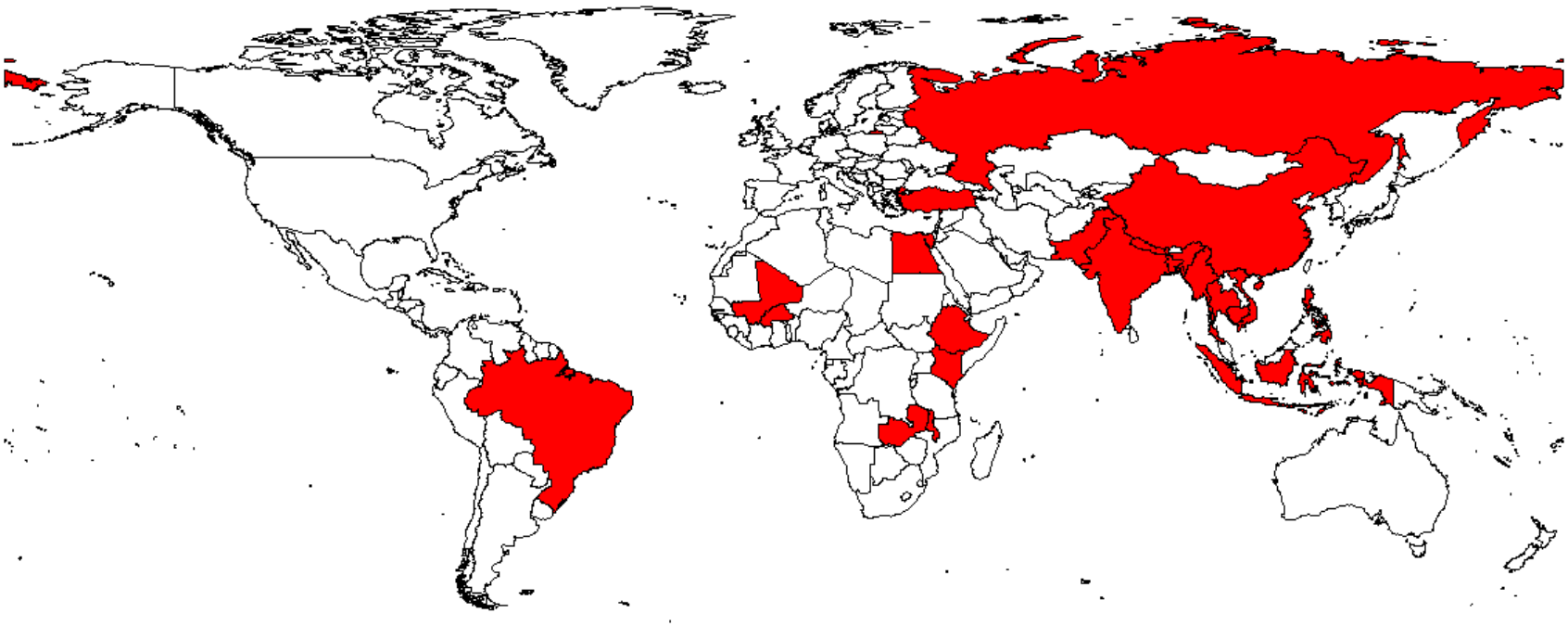

Figure: Countries with high market intervention. Source: Own research.

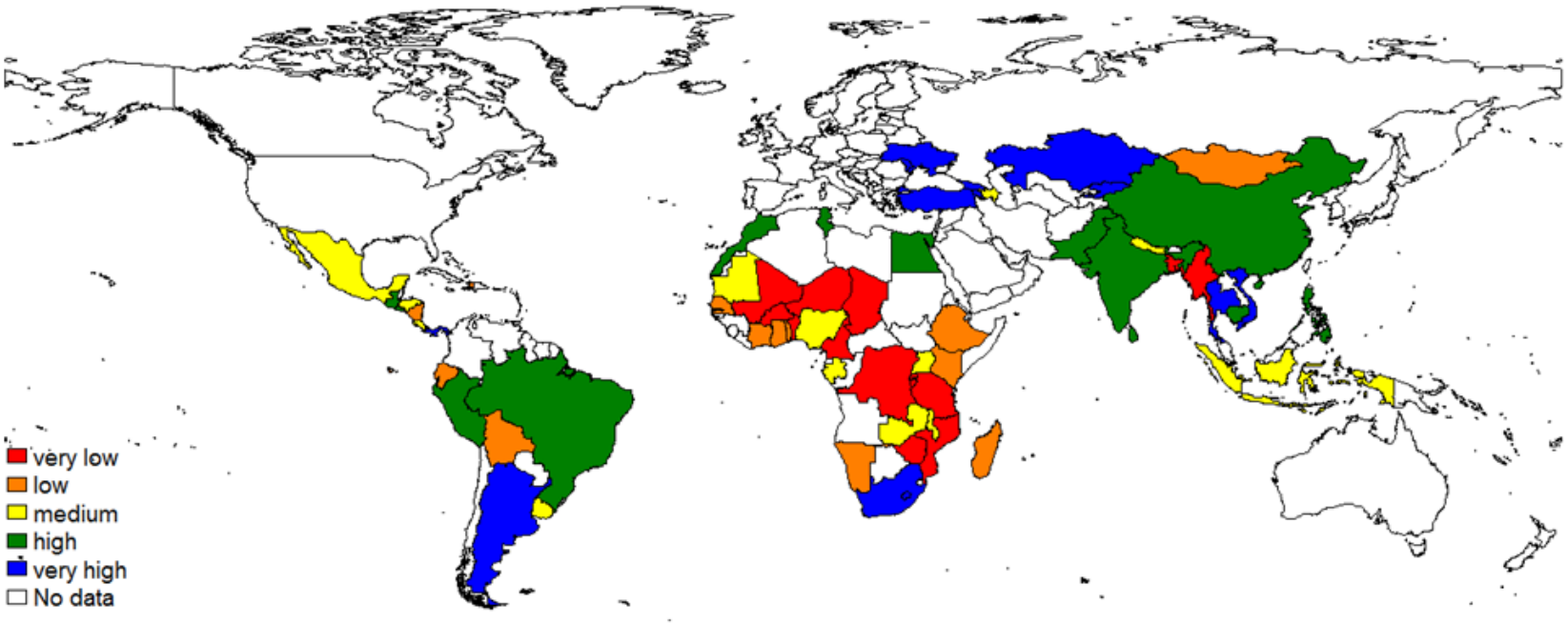

Figure: Market institutions (2000-2012). Institutional quality is measured as an equally weighted average between road infrastructure, mobile penetration and an economic freedom index, and the presence of an agricultural commodity exchange in the country.

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