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Commodity dependence and price volatility in least developed countries: A structuralist computable general equilibrium model with applications to Burkina Faso, Ethiopia and Mozambique

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Commodity dependence and price volatility in least developed countries: A structuralist computable general equilibrium model with applications to Burkina Faso, Ethiopia and Mozambique

Vienna, June 2015

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List of Abbreviations

ADA	Austrian Development Agency
CGE	Computable General Equilibrium
GDP	Gross Domestic Product
GTAP	Global Trade Analysis Project
IMF	International Monetary Fund
KDE	Kernel Density Estimate
LDCs	Least Developed Countries
SAMs	Social Accounting Matrices
SSA	Sub-Saharan Africa
UNCTAD	United Nations Conference on Trade and Development

Abstract

Many least developed countries (LDCs) face commodity dependence on the export and import side. This paper develops a structuralist computable general equilibrium model for commodity-dependent LDCs and simulates global commodity price shocks for Burkina Faso, Ethiopia and Mozambique. Results show important macroeconomic and distributional effects. Although increasing export commodity prices are beneficial, the high correlation with import commodity prices causes low or even negative combined effects. The magnitude of effects depends on the economic structure, the degree of import and export dependence, the production structure of the key commodity sectors and the distribution of windfall profits.

Keywords: *Commodity Dependence; Price Volatility; Sub-Saharan Africa*

1. Introduction

Commodity dependence remains an important issue in many least developed countries (LDCs), particularly in Sub-Saharan Africa (SSA). This implies a high degree of concentration of exports in primary commodities, often dominated by one product, and a relatively high degree of concentration of imports. The latter primarily concerns oil, but as well foodstuffs. Hence, international commodity price developments have important development implications for these countries.

Official trade statistics underline the relevance of commodity dependence in many SSA economies. Between 1995 and 2013, the top three merchandise exports (3-digit SITC codes) from SSA countries were composed exclusively of primary commodities, accounting for 46 percent of total exports on average. The share of all primary commodities in total SSA merchandise exports sums up to more than 77 percent in 2013 with oil exports dominating (with a share of 47.8 percent)¹. Moreover, SSA countries are often specialized in one or few primary commodities, leading to an export concentration index of 0.42 compared to 0.12 in Southeast Asian developing countries and 0.07 in developed countries in 2013 (UNCTADstat). In 48 out of 49 SSA countries included in the UNCTAD Handbook of Statistics 2014, a primary commodity was the main export good in 2013 with an average share of 42.3 percent of total merchandise exports.

Merchandise imports to SSA countries are less concentrated due to the also large import share of manufactured goods. However, in non-oil producing countries oil imports are relatively large, lifting the overall SSA import share of fuels to 12.1 percent between 1995 and 2013. Also SSA food imports, particularly wheat and rice, account for 12.8 percent over the same time period and are often of critical importance given their role in ensuring livelihoods.

While these trade patterns with regard to primary commodities remained relatively stable over the last decades, commodity prices dynamics have changed drastically. After nearly three decades of low commodity prices, commodities have experienced an unprecedented price boom since the early-2000s with price hikes in mid 2008 and 2011. Despite a general decline since April 2014, prices of many commodities particularly agricultural-based remain above their historical levels. A main characteristic of commodity prices is volatility – this has been historically the case but the amplitudes and speed of price changes have increased in the 2000s. This is related to fundamental supply and demand factors as well as technical developments such as electronic trading and the financialisation of commodity derivative markets, i.e. the increased role of financial investors such as investment banks, institutional investors and hedge funds on these markets (Nissanke 2010; UNCTAD 2011; Tröster/Staritz 2013; Ederer et al. 2013).

This paper investigates vulnerability to global commodity price shocks of LDCs in SSA by analyzing the cases of Burkina Faso, Ethiopia and Mozambique. All three countries were dependent on the export of one main commodity – cotton, coffee and aluminum, respectively – and have imported particularly oil and food – mainly wheat and rice. First, we document commodity dependence on the basis of trade data, social accounting matrices (SAMs) and linkage analysis. Second, we put forth a structuralist computable general equilibrium (CGE) model, and simulate selected commodity price shocks. Third, on the basis of the covariance of relevant world commodity prices, we randomly draw a large number of combined shocks, and calculate the counterfactual impacts on macroeconomic balances and indicators as well as household incomes.

¹ This is in sharp contrast to export patterns in developing countries in Southeast Asia where primary commodities represent as little as 18.1 percent of total exports on average.

The results show that world commodity price shocks have important implications on macroeconomic balances and GDP but most importantly have distributional implications. The latter depend on the economic structures of the three countries, particularly the degree of dependence on the top export commodity and existence of a dynamic modern sector, the production structure of the key commodity sector in terms of capital versus labor intensity, distribution of windfall profits and input intensity, and the degree of oil and food import dependence.

The CGE model is based on structuralist fixed-flex price models originated by Hicks (1965), and advanced in Taylor (1983) and Rada (2007), including a quantity adjusting modern sector and allowing for labor movement between modern and subsistence sectors. An export commodity sector is modeled explicitly. The database are existing SAMs for the three countries that also serve as source for Global Trade Analysis Project (GTAP) 8. The SAMs are consistent with macroeconomic data of the respective economies and adjusted to explicitly report flows of funds. SAM adjustment and the model calibration are based on macro, trade and industry data and particularly fieldwork on the main commodity export sectors in the three SSA countries in fall 2014. During fieldwork semi-structured interviews were conducted with farmers' organizations, local traders and processors, industry associations, relevant government institutions and international traders.

This paper has five sections. Section 2 gives an overview of commodity dependence in the three SSA countries based on the adjusted SAMs. The next section introduces the CGE model structure and calibration. Section 4 reports and interprets simulation results of selected shocks and of a randomized combination of world commodity price shocks. The last section concludes.

2. Commodity dependence in Sub-Saharan Africa

Burkina Faso, Ethiopia and Mozambique are commodity-dependent economies. In 2005, they had export concentration indices of 0.75, 0.38 and 0.61, respectively. In the case of Burkina Faso and Mozambique this was even significantly above the SSA average of 0.42. Despite a decline in the concentration index in all three countries since then, this improvement reflects mainly a diversification towards two or more primary commodities compared to a single commodity before. Moreover, all three countries show continuously high concentration levels on the import side, due to the significance of oil imports ranging from 9 to 15 percent of merchandise imports between 1995 and 2013. Wheat and rice imports are also important accounting for between 3.9 and 5.5 percent in the same time period (UNCTADstat).

The baseline database of the structuralist CGE model takes the form of an aggregated SAM. The principles applied to construct SAMs are well known; for comprehensive discussions see, for example, Pyatt (1988) and Taylor (1983, 1990, 2004). We use national SAMs provided by international and national institutions and retain the specific base years (which is 2005 for Burkina Faso, 2005/06 for Ethiopia and 2007 for Mozambique). The SAMs are aggregated into four sectors – a modern sector that produces modern goods and services, an export commodity sector that produces commodities almost exclusively for export, an energy sector largely responsible for the import and provision of energy related goods (oil, fuels, gas, electricity, fertilizers) and a subsistence agricultural sector specialized in food commodities. The economy has three households – capitalists, modern sector households and subsistence households – that derive their income from different sectors and activities and have different consumption propensities and consumption floors. For specific issues concerning the construction of the SAM for the three countries, see Appendix A1.

In this section we highlight some stylized facts derived from the three SAMs to show commodity dependence of the three countries as well as their structural differences.

First, all three countries are dependent on the export of one commodity, albeit to different degrees. Burkina Faso has been traditionally dependent on the production and export of cotton. This has only changed recently with gold being found in Burkina Faso in 2008 that has increased importantly in export shares, accounting for 50 percent of total exports in 2013. Before the discovery of gold, cotton accounted for more than half of total exports. As a share of GDP (at factor cost) the cotton sector contributed only a minor share of 5.3 percent in the base year (Table 1). Mozambique is similarly dependent on the export of aluminum accounting for 53.9 percent of exports and 7.4 percent of GDP in the base year (Table 3). Ethiopia's main commodity exports are coffee and oil seeds, specifically sesame. Both account for 25.8 percent of exports and 5 percent of GDP at factor costs in the base year (Table 2). However, the single largest export revenue comes from transport services which can be attributed to Ethiopian Airlines and is included in the modern sector. In contrast to the other two economies, coffee and oil seeds are also consumed domestically accounting for a share of 31 and 5 percent of total output respectively (see Table 4 for further details).

Table 1: Social Accounting Matrix for Burkina Faso

	Ind	Exp	Ene	Agr	HH (M)	HH (S)	HH (C)	Gov	ROW	CAP	SUM
Industry	828	42	23	23	593	200	602	836	105	292	3544
Export	1			1					155	53	210
Energy	181	40	11	47	60	13	61			7	420
Agriculture	111			27	181	130	184		21	40	694
HH (Modern)	543		16	309							868
HH (Sub.)		113		209							322
HH (Cap.)	1,227	19	75								1321
Government	225	-4	50	12	33	-21	265		120		680
ROW	428	0	244	67							739
FOF							209	-155	338	-392	0
SUM	3,544	210	420	694	868	322	1,321	680	739	0	

In billion CFA franc. HH = Households, ROW = Rest of the World, FOF = Flows of Funds

Source: Balma/Lacina (2012) and authors' calculation.

Table 2: Social Accounting Matrix for Ethiopia

	Ind	Exp	Ene	Agr	HH (M)	HH (S)	HH (C)	Gov	ROW	CAP	SUM
Industry	62.7	1.5	3.3	4.6	41.4	12.0	23.3	27.3	10.7	20.8	207.5
Export	1.1	0.4			1.1	0.6	0.6		4.2		8.1
Energy	8.1	0.1	0.1	1.8	1.0	0.1	0.4		0.0		11.6
Agriculture	2.1			2.4	16.5	8.3	9.3		1.5	0.2	40.3
HH (Modern)	33.3		0.1	12.8					15.7		61.9
HH (Sub.)		3.8		16.5							20.3
HH (Cap.)	52.5	2.2	0.9								55.7
Government	9.8	0.0	0.2	0.1	1.9	-0.7	6.7		3.3		21.3
ROW	37.8	0.0	7.0	2.2							47.0
FOF							15.4	-6.1	11.6	-21.0	0.0
SUM	207.5	8.1	11.6	40.3	61.9	20.3	55.7	21.3	47.0	0.0	

In billion Birr (ETB). HH = Households, ROW = Rest of the World, FOF = Flows of Funds

Source: EDRI (2009) and authors' calculation.

Table 3: Social Accounting Matrix for Mozambique

	Ind	Exp	Ene	Agr	HH (M)	HH (S)	HH (C)	Gov	ROW	CAP	SUM
Industry	103.7	11.3	5.5	10.2	65.2	15.5	30.5	38.2	24.9	18.0	323.0
Export	1.1	0.7	0.1						44.4		46.3
Energy	14.0	5.7	1.0	0.3	7.0	1.3	2.4		9.9		41.6
Agriculture	3.3			3.9	28.1	9.0	12.8		3.0	1.5	61.6
HH (Modern)	82.0	2.7	3.8	14.6					2.0		105.1
HH (Sub.)				25.8					-		25.8
HH (Cap.)	46.3	11.8	9.0						-15.0		52.1
Government	6.9	0.1	2.6	0.3	4.9		4.4		13.0		32.1
ROW	65.6	14.0	19.6	6.6							105.8
FOF							2.0	-6.0	23.6	-19.6	0.0
SUM	323.0	46.3	41.6	61.6	105.1	25.8	52.1	32.1	105.8	0.0	

In billion Metical (MZN). HH = Households, ROW = Rest of the World, FOF = Flows of Funds

Source: Arndt/Pauw/Thurlow (2012) and authors' calculation.

Table 4: Selected country statistics

	Burkina Faso (2005)	Ethiopia (2005/06)	Mozambique (2007)
Net borrowing flows			
(I-S)/GDP	7.3	4.6	9.0
(G-T)/GDP	6.2	5.0	3.1
(E-M)/GDP	-13.4	-9.5	-12.0
Trade shares			
Export/GDP	11.2	13.4	41.9
Export share of commodity	55.0	25.8	54.0
Import/GDP	29.4	38.5	54.0
Import share of commodities	42.1	19.5	24.7
Income shares			
Modern	34.6	37.8	52.6
Subsistence	12.8	16.6	13.1
Capitalist	52.6	45.6	34.2
Consumption shares			
Modern	41.2	52.3	58.4
Subsistence	16.9	18.4	15.0
Capitalist	41.9	29.3	26.6

Source: Country SAMs and authors' calculation.

In all three countries, the aggregated modern industry and services sector includes most activities of the economy and accounts for 65 to 70 percent of value added. It is further important in terms of linkages as other sectors show much smaller linkages and hence multiplier effects (see Appendix A2 for a description on the calculation of linkages). Particularly the export commodity sectors have very weak relative forward linkages of 0.77, 0.74 and 0.72 for Burkina Faso, Ethiopia and Mozambique respectively² confirming that these countries largely export unprocessed commodities without any major local processing activities (Table 5 and Figure 1). The energy sector only has a substantial own production in Mozambique due to the Cahora Bassa hydroelectric power plant and gas extraction. In the other two countries it largely organizes the import and domestic distribution of energy.

² It should be noted that the linkage analysis is implicitly based on the assumption that no significant supply constraints exist. Linkages would be lower if these were fully accounted for.

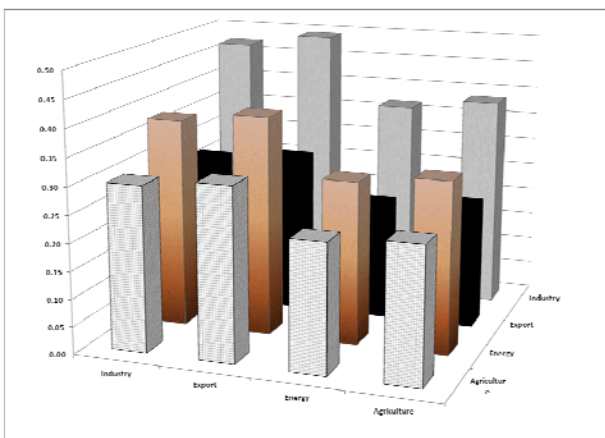
Table 5: Linkage analysis

		Industry	Export	Energy	Agriculture
Burkina Faso	BW	1.10	1.15	0.85	0.90
	FW	1.32	0.77	1.07	0.84
Ethiopia	BW	1.08	0.96	1.05	0.92
	FW	1.66	0.74	0.85	0.75
Mozambique	BW	1.10	1.09	0.86	0.94
	FW	1.64	0.72	0.88	0.76

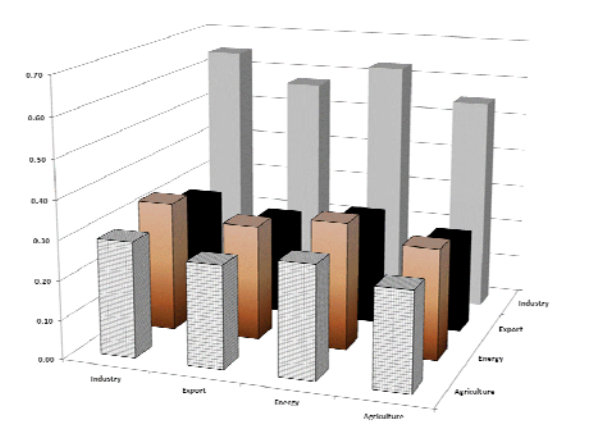
The table shows measures of *relative* backward (BW) and forward (FW) linkages. Backward (forward) linkages are columns (row) sums of the Leontief inverse, divided by the ‘average intensity,’ which is the average of all elements of the Leontief inverse. Values above unity indicate strong linkages. See Appendix A2 for further detail on the calculation.

Figure 1: Input-output linkages

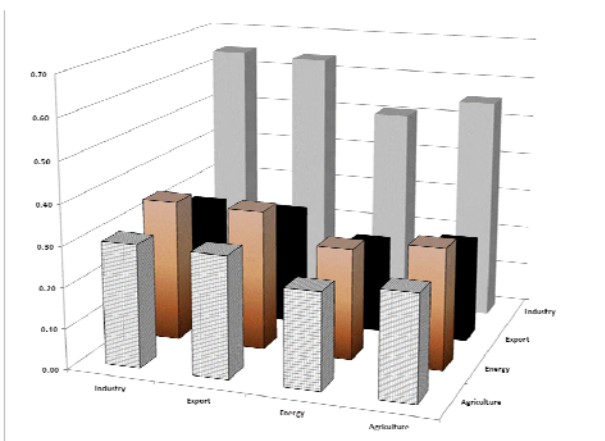
Burkina Faso



Ethiopia



Mozambique



The grid represents a matrix of “multiplier products:” Each element is the product of the two sectors’ respective forward and backward linkage. See Appendix A2.

Second, the structure of the commodity export sector differs along several dimensions – capital versus labor intensive production process, distribution of windfall profits, and input intensity. Cotton and coffee are agriculture commodities where small holder farming plays a dominate role in production – also in Burkina Faso and Ethiopia where more than 95 percent of production comes from small holder farmers. Hence, subsistence households are directly involved in commodity production and also receive a share of the windfall profits if world

commodity prices increase. This is however not necessarily the case in labor-intensive commodity sectors but depends on the negotiations and power structures between farmers, local intermediaries (ginners in the case of cotton and processors and exporters in the case of coffee) and international traders that govern trade in these sectors. Both countries have institutional structures in place that secure that a certain share of world prices goes to farmers – in Burkina Faso due to a regional concession system and a national price setting scheme with a two tier payment and a smoothing fund (for more details see Staritz et al. 2015a) and in Ethiopia due to the Ethiopian Commodity Exchange, national regulations and co-operative structures that provide price transparency and implicit minimum prices (for more details see Tröster/Staritz 2015). Hence, potential windfall profits accrue to capitalist households and subsistence households.³

In contrast, aluminum production is capital and energy intensive involving the smelting of alumina, i.e. aluminum oxide refined from bauxite, which is done in a smelter owned by foreign investors – the mining giant BHP Billiton (47 percent), Mitsubishi (25 percent) and Industrial Development Corporation of South Africa (24 percent). The government of Mozambique owns the remaining four percent (Friends of Earth Mozambique 2012). Employment effects are minimal and only affect modern households. Hence, potential windfall profits accrue largely to – in this case foreign – capitalist households with a large share leaving the country as repatriated profits to foreign equity owners.

Besides the production process and different household types involved in the export commodity sector, there are also crucial differences in input intensity. Coffee is the least input and also import intensive sector as small holder coffee producers in Ethiopia hardly use fertilizers, herbicides or pesticides. Modern sector inputs are mostly transportation services. Cotton is more input intensive using pesticides and fertilizers and through the necessity to gin cotton before exporting also machinery for the ginning process. These inputs are largely imported. Both agriculture sectors require relative little energy. Aluminum production, on the other hand, is very energy intensive and requires the import of alumina as intermediate good as Mozambique does not have bauxite reserves. In addition, chemicals and machinery from the modern sector are required as inputs, which are also largely imported.

These different structures of the commodity export sectors can be seen in relative backward linkages that are the lowest in Ethiopia (0.96) followed by Mozambique (1.09) and Burkina Faso (1.15) (Table 5 and Figure 1). These linkages come from the modern and the energy sector in form of transportation services (in all countries), electricity (Mozambique), and fertilizers and pesticides (Burkina Faso)⁴.

Third, even though all three countries import oil and to a lesser extent food, specifically wheat and rice, their commodity import dependence varies. Burkina Faso has the highest share of energy imports including fertilizers (33 percent) and food imports (9 percent) in total imports. Also, Mozambique has a relatively high share of energy imports (19 percent) despite the own production of electricity and natural gas and devotes 6 percent of import expenditures on food commodities. Ethiopia has the lowest shares with 15 percent for energy imports and 5 percent for food imports. Regarding the import penetration ratio (imports to total demand), the agricultural sector in Mozambique has the highest share for food commodities with 10.6 percent (compared to 9.6 percent and 5.4 percent in Burkina Faso and Ethiopia respectively).

³ In Ethiopia price declines are directly transmitted to farmers while Burkina Faso is one of the few SSA countries that still has national pan-seasonal national price setting arrangements where price declines are not transmitted to farmers during the season as this system secures a fixed price over the whole season (Staritz/Tröster 2015).

⁴ In Burkina Faso almost all fertilizers and pesticides are imported, only two out of around 60 fertilizer and pesticide firms are mixing chemicals locally; the rest only distributes imported fertilizers and pesticides to cotton companies via tenders.

In summary, Table 6 shows the main structural differences in the three SSA commodity-dependent LDCs that importantly influence the outcomes of world commodity price shocks on GDP, macroeconomic balances and distribution.

Table 6: Comparison of economic structure

		Burkina Faso	Ethiopia	Mozambique
Commodity export dependence (share of major export commodity in % of total exports)		High (54.6)	Lower (25.4)	High (53.9)
Production structure in commodity export sector	<i>Capital vs. labor intensity</i>	Labor-intensive	Labor-intensive	Capital-intensive
	<i>Distribution of windfall profits</i>	Capitalists and subsistence households	Capitalists and subsistence households	Foreign capitalists and modern sector households
	<i>Input intensity</i>	medium	low	high
Oil and food import dependence		high	Low	Medium

Commodity export and import dependence is generally high for these commodity-dependent countries; so higher and lower are to be seen in relative terms. The export share is calculated as the export share of the selected export commodities in the respective SAMs.

3. A structuralist computable general equilibrium model for commodity-dependent economies

The CGE model builds on fixed-flex price models initially developed by Hicks (1965), Kalecki (1972) and Taylor (1983). The defining feature of these models is that prices in the industrial or modern sector are fixed due to excess capacity, while supply-constrained output in the agricultural or subsistence sector causes price adjustments. Our contribution is to emphasize “commodity dependence” in such a framework.⁵

To do so, our model is extended by two sectors: a commodity export sector and an energy (import) sector. The commodity export sector depicts production and income flows related to the single (or few) commodities that are exported, and the energy sector describes the provision of energy related goods (oil, fuels, gas, electricity, fertilizers) to households and firms. In the three countries considered, the latter activity crucially relies on imports of oil. In this vein, our aggregation scheme highlights the core issues of commodity dependence: a supply constrained commodity export sector generates foreign exchange; a supply constrained subsistence sector dependent on food imports or imported intermediates provides basic foodstuffs; and a “utility sector” dependent on oil imports provides necessary energy – and all three of these are subject to world price fluctuations.

A modern sector – in turn, largely dependent on imports of foreign machinery – complements the picture. The modern sector produces goods and services with relatively complex production processes including the use of capital. This also captures some agricultural activities, if they are organized in such a way (for example, large commercial farms). Firms are

⁵ The model has been advanced by Rada (2007); von Arnim/Rada (2011) and Rada/von Arnim (2012; 2014) show applications and extensions. A similar approach is put forth by Storm (1997); see also Davies/Rattso (1996) and De Maio et al. (1999). The model focuses on the real side; for a related discussion of financial issues, see Robinson (1991). The following paragraphs detail the four sector model and the closure rules used. The underlying principles are otherwise standard for a structuralist CGE model: The technology is Leontief, nominal unit labor costs are constant, and prices follow from the cost decomposition. Consumption demands are determined in a linear expenditure system, investment flows are (largely) exogenous, and trade flows are constant elasticity functions of relative prices and activity levels. The rest of the world – as described by world prices and a shift factor in export functions – is exogenous.

assumed to have excess capacity, and are price setters. In other words, the sector features flexible quantities, and relatively fixed prices. Prices are 'relatively' fixed in the sense that factor cost index and output prices are tied down by nominal unit labor costs, which are assumed constant. With fixed labor productivity, employment growth is determined by output growth.

The export commodity sector produces commodities (almost) exclusively for export. The majority of demand for this product comes from abroad, and its exports make up a large portion of overall exports. The sector is assumed to be supply-constrained, and price-adjusting. Put differently, real output is fixed, and prices change to render excess demand zero. More specifically, it is assumed that the mark-up rate rises with excess demand, so that capitalists, through windfall profits, absorb price and demand shocks from abroad in the first place, since they cannot translate into expansion of production. These windfall profits are divided among capitalists and the relevant households according to a distribution rule (see below). As in the modern sector, with fixed labor productivity, employment growth is determined by output growth.

The energy sector is assumed to feature excess capacity, and price setting similar to the modern sector. It differs from the latter primarily in its structure, namely low domestic value added, low employment, and high import-to-output ratio. This structure implies that domestic energy supply prices are driven largely by world oil prices, since imported oil dominates the sectoral cost structure. As the simulations below demonstrate, the sector is in principle similar to the modern sector, but in practice quite different. Here as well, employment growth is determined by output growth.

The agricultural sector produces basic foodstuffs only. It is expected to encounter constraints on the supply side due to limited availability of acreage, inputs, capital and technology. Consequently, the sector is price-adjusting. Specifically, output is fixed and the nominal wage is endogenous. The implicit causality assumption is that the output price equilibrates demand and supply, and the nominal wage adjusts to satisfy the income identity. Since all income is informal, i.e. 'market revenue' of small proprietors, the income identity simply implies that the real wage is equal to average labor productivity. The latter, however, depends on the amount of employment and changes with labor transfers: given demand from the other sectors, this sector's surplus labor can be transferred there. If the modern sector experiences expansion, it will absorb surplus labor from the agricultural sector – where labor productivity rises. In consequence, (economy-wide) average labor productivity increases.

In summary, modern and energy related activities feature demand-driven output and cost-driven prices; with the crucial difference lying in the (import) cost structure, and the high volatility of world oil prices. The export commodity and agricultural sectors are supply-constrained, and thus price adjusting. In the former, it is the mark-up of capital owners that rises with world price increases; in the latter, it is household income in the form of wages that rises with excess demand for foodstuffs.

Such closure rules imply that a demand shock – say, from the modern sector – percolates through the economy via intermediate linkages, consumption demands and trade flows due to relative price and activity changes. In the two supply-constrained sectors, however, the higher demand cannot be satisfied. Resulting inflation through mark-up or wage increases reduces real incomes and demand to restore a situation of macroeconomic balance. The labor transfer mechanism plays an important role in the adjustment (as the discussion of simulations below details).

These quite standard fixed-flex price model dynamics are augmented with a *windfall profit distribution rule* in the export commodity sector. We define windfall profits as the change in

nominal value added attributable to a change in the mark-up rate. To illustrate, and without sectoral indices for brevity, suppose that PY is nominal sectoral value added in the commodity export sector, W the wage bill, and τ_0, τ the base year and current, endogenous mark-up rate on wage costs, respectively. Then, $PY = (1 + \tau)W$, and windfall profits π – equal the change in nominal value added due to the mark-up rate – are $\pi = (\tau - \tau_0)W$.

This total flow of windfall gains is divided among the three households according to the distribution rule: modern households and subsistence households obtain a fixed share and capitalists the remainder. Crucially, in Burkina Faso and Ethiopia, subsistence households earn a majority share of windfall gains (60 percent), whereas only modern households obtain one fifth in Mozambique (for assumptions see the discussion above). Modern and subsistence households spend their gains on consumption. Capitalists, in contrast, consume and re-invest a fixed portion. In Burkina Faso and Mozambique, 50 percent is consumed and the other half invested in the industry sector as domestic capitalists also own modern sector businesses. In Mozambique, where capital is held overwhelmingly by foreigners, the majority of windfall profits accruing to capitalists are expatriated (70 percent) with the rest invested in the export commodity sector. Table 7 reports the assumed shares.

Further, trade elasticity values play an important role in determining model results. We assume low values for imports in the commodity, energy provision and agriculture sectors due to the dependence on foodstuffs and energy commodities. On the export side, industry and agricultural goods are price sensitive with trade elasticity values of one, while a value of 0.5 is assumed for the export commodity (which is only relevant for Ethiopia, as the only country with domestic consumption of the main export goods). See as well Table 7 for an overview.

Table 7: Calibration

	Ethiopia	Burkina Faso	Mozambique	<i>Trade price elasticities</i>	
(1) Modern			0.2		
(2) Subsistence	0.6	0.6		Imports	Exports
(3) Capitalist	0.4	0.4	0.8	Industry	0.5
				Export com.	0
(4) Consumption	0.5	0.5		Energy	0
(5) Re-investment	0.5	0.5	0.3	Agriculture	0.1
(6) Capital flight			0.7		1
(7) Re-investment	Industry	Industry	Export com.		

The table summarizes key parameters. In the left part, the top three rows indicate the distribution of windfall profits from commodity export price changes across the three households. Rows (4)-(6) document the use shares of capitalists' windfall profits. Row (7) indicates in which sector re-investment takes place. The right side of the table reports the trade price elasticities, which are assumed to be the same across the three countries.

4. Simulations

In this section we discuss simulation results. Altogether, six scenarios are considered, including (1) an investment demand increase in industry (representing one per cent of GDP); (2) an increase in the nominal exchange rate, i.e. a nominal devaluation (by 10 percent); and an increase (3) in the world price of oil; (4) in the world price of the respective export commodity; (5) in the world price of industrial imports and (6) in the world price of food imports. Global benchmark prices in (3) to (6) are increased by 10 percent in each case.⁶ The results are summarized in Table 8 and indicate changes in selected balances and variables relative to the calibration in the base year defined by the SAM data.

⁶ Although we include only price increases in this analysis, the results can also be adopted for decreasing prices.

4.1. Illustrative selected shocks

The focus of this paper is on commodity price shocks. Thus, the results of oil, food and export commodities price shocks are highlighted here. Specifically, the distributional effects are of interest.

Table 8: Simulation results

		(1)	(2)	(3)	(4)	(5)	(6)
		Investment	Exchange rate	Oil	Export commodity	World manufactures	Food import
Burkina Faso (Cotton)	(I-S)/GDP	0.7	0.4	0.3	-0.1	0.1	0.1
	(G-T)/GDP	-0.5	-0.1	0.5	-0.5	0.3	0.1
	(E-M)/GDP	-0.2	-0.3	-0.8	0.6	-0.4	-0.1
	Real GDP	1.5	0.3	-1.2	1.2	0.5	-0.2
	Modern	2.2	-2.7	-3.3	2.0	-0.8	-0.6
	Subsistence	2.1	0.2	-4.3	6.7	-1.4	-0.7
	Capitalist	1.4	-2.2	-2.0	0.7	-0.6	-0.3
	CPI	0.6	2.8	0.3	1.3	1.2	0.0
	RER	-0.6	7.0	3.0	-1.3	4.4	0.9
Con. real wage	2.1	-2.8	-3.4	2.2	-0.9	-0.6	
Ethiopia (Coffee)	(I-S)/GDP	0.7	0.1	0.2	-0.1	0.4	0.0
	(G-T)/GDP	-0.3	-0.2	0.2	-0.1	0.4	0.0
	(E-M)/GDP	-0.4	0.1	-0.4	0.3	-0.8	0.0
	Real GDP	1.1	1.6	-0.6	0.4	0.5	0.0
	Modern	1.0	0.9	-1.2	0.2	-1.9	-0.1
	Subsistence	1.8	1.6	-2.3	2.9	-3.1	0.0
	Capitalist	1.2	-1.4	-1.1	0.2	-1.4	-0.2
	CPI	0.3	3.8	0.3	0.5	2.1	0.1
	RER	-0.3	5.9	1.2	-0.5	5.8	0.3
Con. real wage	1.5	-0.7	-1.8	0.6	-2.2	-0.1	
Mozambique (Alum.)	(I-S)/GDP	0.8	0.2	0.2	-0.2	0.2	0.0
	(G-T)/GDP	-0.2	-0.3	0.2	-0.2	0.4	0.0
	(E-M)/GDP	-0.5	0.1	-0.3	0.3	-0.6	-0.1
	Real GDP	1.4	0.5	-0.9	0.4	1.0	-0.2
	Modern	2.2	1.3	-1.5	1.5	1.1	-0.3
	Subsistence	4.0	-1.1	-3.2	2.1	0.2	-0.8
	Capitalist	2.0	0.6	-1.3	0.6	1.4	-0.3
	CPI	0.4	4.1	0.4	1.4	2.2	0.1
	RER	-0.4	5.7	1.5	-0.1	3.9	0.5
Con. real wage	2.2	-3.9	-2.2	-0.3	-1.1	-0.5	

The table presents simulation results for selected shocks for each country. The shocks are (1) an investment demand increase (representing one per cent of GDP) in industry; and a 10 per cent increase in (2) the nominal exchange rate, i.e. a nominal devaluation; (3) in the world price of oil; (4) in the world price of the respective export commodity; (5) in the world price of industrial imports and (6) in the world price of food imports. The first three rows for each country report changes in net borrowing flows. (The investment shock in Ethiopia leads to an increase in private net borrowing of about seven-tenth of one percentage point of GDP, and a reduction of the budget deficit of three-tenth of one percentage point of GDP, etc.) The following rows report growth rates. "Modern," "subsistence" and "capitalist" are household incomes of these respective classes. RER is the real exchange rate, and the last row the employment weighted consumption real wage.

In general, real GDP is largely influenced by output in the modern sector due to the importance of the sector in our aggregation. However, labor transfers between agricultural and modern sectors as well as the distribution rule of windfall profits are crucial for the demand side and for household incomes, specifically in the subsistence sector. For instance, an investment shock in the modern sector (one percent of GDP) has a multiplying effect on the countries' real GDP. The largest increase is however noticeable in the subsistence household income due to labor movements.

Regarding *export commodity price shocks*, the relevance of specific commodities on the export side links higher global prices of these commodities to higher real GDP in all countries. The magnitude differs, however, with Ethiopia showing modest growth in real GDP (0.41 percent) and current account improvement (0.28 percentage points relative to GDP). One reason is the lower share of coffee and oilseeds in total exports relative to the commodity export patterns in the other countries. Subsistence households, however, see a clear increase (2.91 percent) mainly due to the assumed distribution of 60 percent of windfall profits to these households. The results for Burkina Faso and Mozambique differ despite the fact that these two countries have a similar share of the export commodity in total exports (of around 54 percent). In Burkina Faso, the labor-intensive production process and institutional settings redirects windfall profits towards subsistence households. Also modern households benefit via higher investments from capitalists and increased consumption by subsistence households. Hence, real GDP grows by 1.22 percent in this scenario. In Mozambique, on the other hand, the effect of higher export commodity prices is significantly lower for several reasons. First, the aluminum production in Mozambique requires the more costly import of alumina. Second, a substantial part of windfall profits flows out of the country to foreign capitalists. So only the 20 percent of windfall profits going to domestic workers (and the 24 percent of capitalists' income being locally reinvested in the export commodity sector) can stimulate consumption and labor transfer (causing also higher subsistence household incomes) which limits the overall effect to a real GDP increase of 0.43 percent. The key model feature driving results in this scenario is the distribution rule of windfall profits that arise with higher global prices and supply constraints in the export commodity sectors.

The described results are induced by isolated price movements. In recent years and related to financialisation, prices of various commodities were observed to move with close correlation (Ederer et al.,2013). Therefore, the next step is to randomize combinations of simultaneous commodity price shocks.

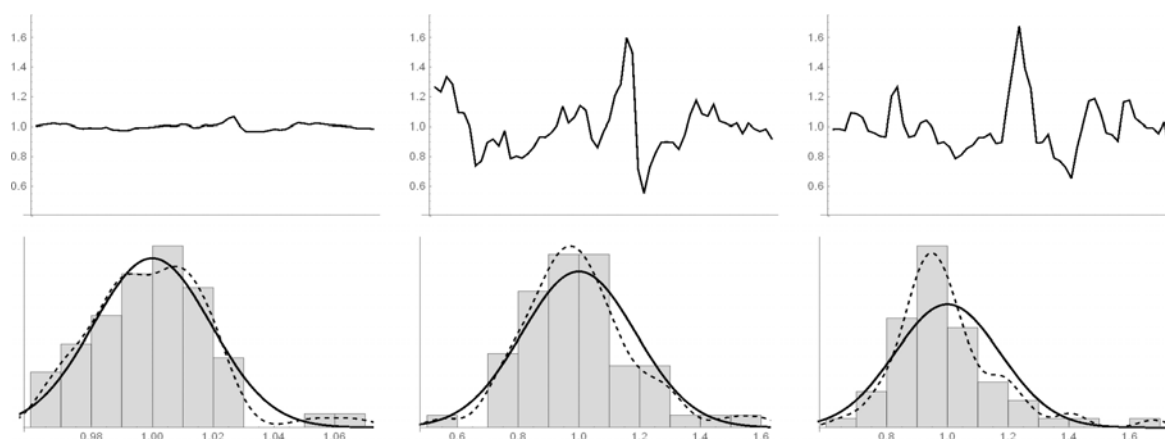
4.2. Random draws of world commodity price shocks

In order to show the impact of combined commodity price changes, quarterly observations from import and export commodity prices (global benchmarks) in the period from Q1 2000 to Q3 2014 are used. Figure 2 shows cyclical variations of the three world price indices common to all three countries: world manufacturing prices, world oil prices and world wheat prices representing prices of foodstuffs. In Figure 3 cyclical variations of the three export commodity price indices of Ethiopia (coffee, vegetable oil), Burkina Faso (cotton) and Mozambique (aluminum) are shown.⁷ The bottom panels of Figure 2 and 3 show histograms of price distributions against normal distributions with the respective standard deviation (solid).⁸

⁷ The cyclical variations are obtained as the ratio of actual, quarterly observations to the Hodrick-Prescott filter trend (with standard smoothing parameter 1600).

⁸ The dashed line is a smooth Kernel density estimate (KDE), which might be preferable when observations are not normally distributed. As can be seen, the KDE appears to depict the histograms slightly better, especially in the case of cotton. However, overall, the pattern of results – as further discussed below and reported in Table 10 – does not change significantly with either distribution assumed.

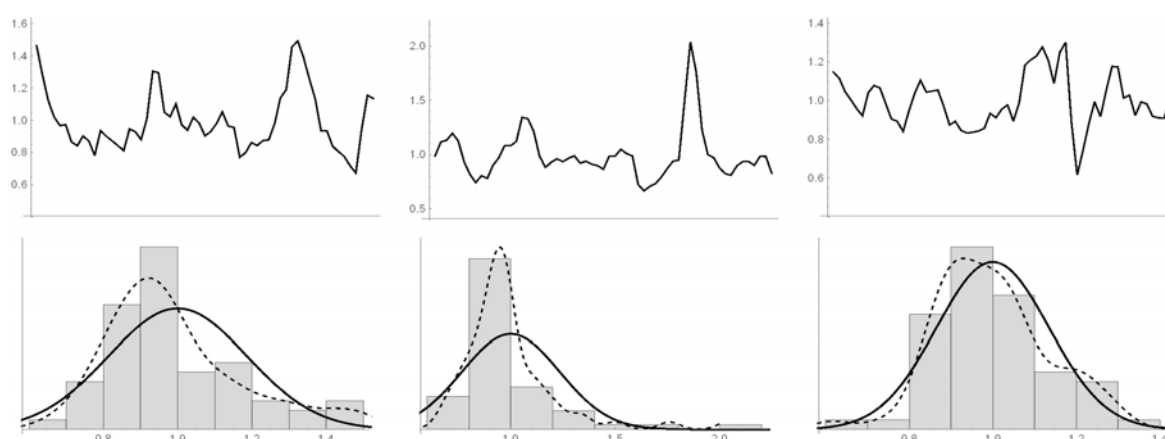
Figure 2: Import price data



The chart shows cyclical variations of (left to right) a world manufactures price index (OECD Manufactures Unit Value), world oil price and world wheat price index. The cyclical variations are obtained as the ratio of actual, quarterly observation (Q1:2000-Q3:2014) to Hodrick-Prescott filter trend (with standard smoothing parameter 1600). The bottom panels show histograms of price distributions against normal distributions with the respective standard deviation (solid) and a smooth Kernel density estimate (dashed).

Sources: OECD.Stat, IMF Primary Commodity Prices and authors' calculation.

Figure 3: Export commodity price data



The chart shows cyclical variations of (left to right) commodity export price indexes of Ethiopia (coffee, vegetable oil), Burkina Faso (cotton) and Mozambique (aluminum). The cyclical variations are obtained as the ratio of actual, quarterly observation (Q1:2000-Q3:2014) to Hodrick-Prescott filter trend (with standard smoothing parameter 1600). The bottom panels show histograms of price distributions against normal distributions with the respective standard deviation (solid) and a smooth Kernel density estimate (dashed).

Sources: IMF Primary Commodity Prices and authors' calculation.

The covariance between the import and the respective export price data are calculated for each country. As reported in Table 9, coffee and cotton prices in Ethiopia and Burkina Faso show a positive covariance with the other commodities during this period, in particular with oil prices. Aluminum prices in Mozambique tend to have a negative covariance with oil and food prices. Consequently, Ethiopia and Burkina Faso might benefit from positive export prices for their commodities, but at the same time, the exposure to downside risk due to higher oil and food import prices increases. In the next step, we draw – based on the sample covariance matrix – a large number ($n = 500$) of random price combinations for each country, and solve each country model n -times. We thus obtain a large number of model outputs in response to price shocks, which seek to replicate observed comovements.

Table 9: Covariance matrizes

Industry	Export	Energy	Agric.				
0.000	0.001	0.003	0.002	0.0	0.1	0.2	0.1
0.001	0.055	0.012	0.013	0.1	4.1	0.9	0.9
0.003	0.012	0.035	0.016	0.2	0.9	2.6	1.2
0.002	0.013	0.016	0.030	0.1	0.9	1.2	2.3

Industry	Export	Energy	Agric.				
0.000	0.001	0.003	0.002	0.0	0.1	0.3	0.2
0.001	0.035	0.014	0.002	0.1	3.2	1.3	0.2
0.003	0.014	0.035	0.016	0.3	1.3	3.2	1.5
0.002	0.002	0.016	0.030	0.2	0.2	1.5	2.7

Industry	Export	Energy	Agric.				
0.000	0.000	0.003	0.002	0.0	0.0	0.4	0.2
0.000	0.018	-0.001	-0.001	0.0	2.4	-0.1	-0.1
0.003	-0.001	0.035	0.016	0.4	-0.1	4.5	2.1
0.002	-0.001	0.016	0.030	0.2	-0.1	2.1	3.9

The left part of the table shows covariance matrizes of the trade price data; for, from top to bottom, Burkina Faso, Ethiopia and Mozambique. The right part shows each entry scaled by the average of the covariance matrix.

Based on this randomization of actual price data, the correlation between the changes in the trade price index and real GDP growth are negative for all three countries. Thus, an increase in import and export prices has an overall depressing effect on real GDP on average. This is true in particular for Ethiopia with a correlation coefficient of -0.46. Mozambique and Burkina Faso show lower correlation coefficients of -0.23 and -0.03, respectively (Table 10). This is the result of contradicting effects from variations in import and export prices. Given that export prices tend to increase with import prices, real GDP might grow due to higher export prices on the one hand, but simultaneously, real GDP will be depressed due to higher import prices. Hence, the overall outcome depends on the magnitude of the contradicting effects.

Table 10: Model responses to random price shock combinations

	Real GDP	CPI (PX)	Mark-up (Export)	Employment (Agric.)	RER	HH (Mod)	HH (Sub)	HH (Cap)
Burkina Faso	-0.03	0.84	0.15	0.00	0.61	-0.38	0.18	-0.63
Ethiopia	-0.46	0.96	0.43	0.45	0.80	-0.89	-0.18	-0.87
Mozambique	-0.23	0.98	0.57	0.21	0.54	-0.52	-0.45	-0.77

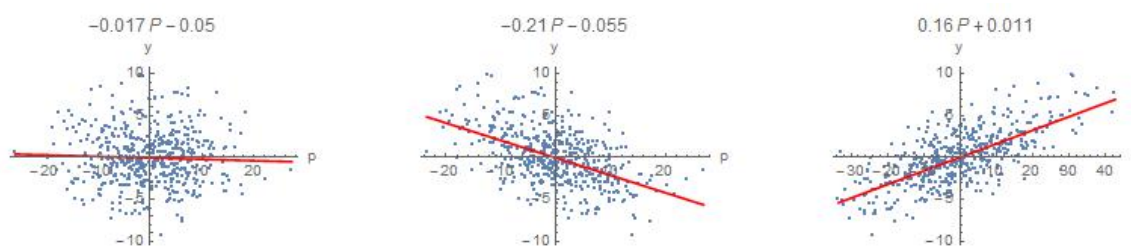
The table shows correlation coefficients between a traded goods price index (PT) and the model results for the variables listed across columns. The index PT captures random combinations of price shocks. HH = Households, RER = Real Exchange Rate

Distributional effects are generally stronger but also different for the three countries. In Ethiopia, due to the share in export windfall profits attributed to small holder farmers, subsistence households are less negatively affected than the other two types of households. In Burkina Faso, the same distributional patterns are noticeable, with windfall distribution effects being even stronger than in Ethiopia. Also labor movement to the agricultural sector is less affected by trade price changes. In the case of Mozambique, subsistence households lack direct income from the export sector. Therefore effects of import price shocks cannot be balanced by higher export earnings.

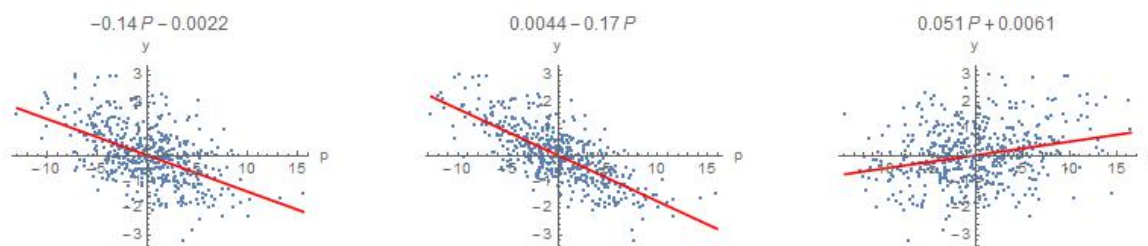
A graphical presentation of the relation between randomized trade price changes and real GDP (Figure 4) and income of subsistence households (YH_2 , Figure 5) further shows the magnitude of and difference in effects of export and import price changes among the three countries. With random draws from normal distributed price changes, the patterns in correlations remain with import and export price shocks leading to negative effects on GDP for all three countries. Regarding YH_2 , outcomes are positive in Burkina Faso but remain negative in the other two countries. In general, the variations in YH_2 due to commodity price changes are significantly higher compared to GDP growth rates, signaling the high vulnerability of subsistence households in these economies.

Figure 4: Real GDP growth and trade price inflation

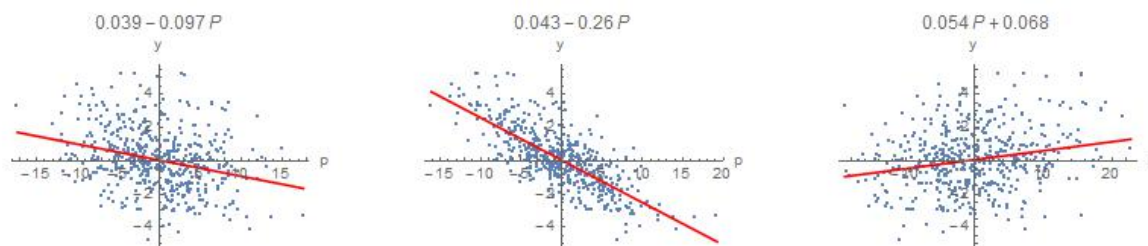
Burkina Faso



Ethiopia



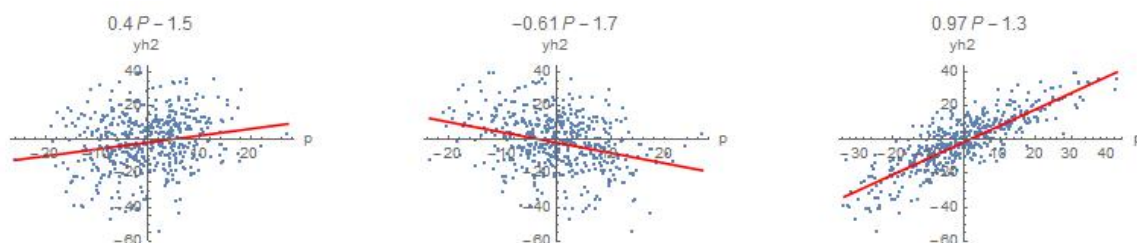
Mozambique



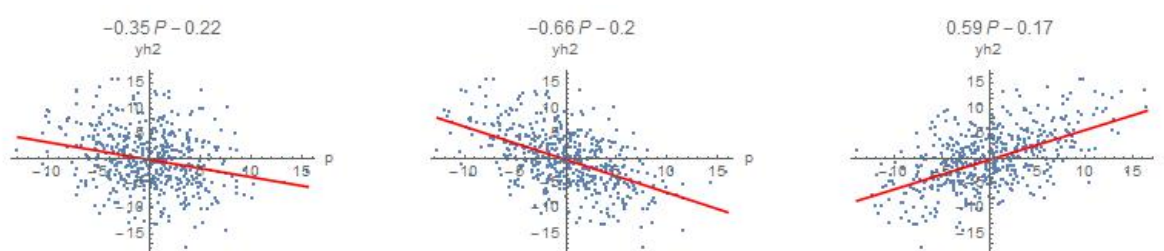
All three relate trade price inflation (p) to GDP growth (y) for, from top to bottom, Burkina Faso, Ethiopia and Mozambique. Left panels are all (Fisher weighted) import and export prices; middle panel only import prices, and right panel only respective export prices. Price inflation (p) is based in normal distributed price changes

Figure 5: Subsistence household income growth and trade price inflation

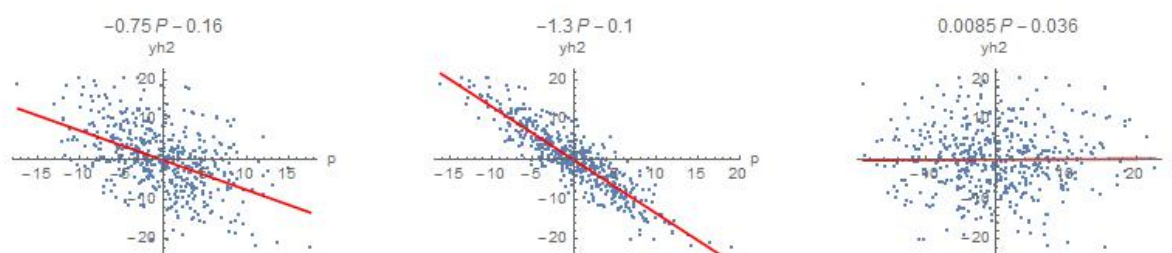
Burkina Faso



Ethiopia



Mozambique



All three relate trade price inflation (p) to growth of subsistence household income (yh_2) for, from top to bottom, Burkina Faso, Ethiopia and Mozambique. Left panels are all (Fisher weighted) import and export prices; middle panel only import prices, and right panel only respective export prices. Price inflation (p) is based in normal distributed price changes.

Simulation results for Burkina Faso show low correlation with all import and export prices, as export earnings can make up potential losses related to higher import prices. The same effects are visible for YH_2 due to the windfall profits distributed to subsistence households, given the positive correlation of cotton and import prices on average. However, the analysis also underlines that YH_2 declines with lower cotton prices, which in many situations might have a stronger effect than lower import prices. In Ethiopia, export price changes correlate positively with real GDP and YH_2 . However, the effects are not strong enough to compensate for the negative correlation with import prices, leading to a negative correlation overall. In Mozambique the weak positive impact of export prices on real GDP and YH_2 is noticeable. Thus, subsistence households in Mozambique are highly dependent on variations of import commodity prices.

5. Conclusions

The selected countries in SSA – Burkina Faso, Ethiopia and Mozambique – are examples for commodity-dependent economies. The specialization on particularly one export commodity with limited linkages to the domestic economy and the dependence on primary commodity imports, in particular oil and foodstuffs, make these economies highly vulnerable to commodity price volatility.

As shown by the simulation results of our structuralist CGE model, macroeconomic variables and balances (particularly real GDP and the current account) are impacted by commodity price fluctuations. A 10 percent price increase of the major export commodities increases the current account by up to 0.6 percentage points relative to GDP and causes real GDP to grow between 0.4 and 1.2 percent. Regarding the magnitude of these effects, it should be considered that commodity price fluctuations in recent years were significantly higher than 10 percent. For instance, global cotton prices increased from 51.5 to 229.7 US cents between March 2009 and March 2011 and declined to 100 US cents per pound by March 2012. Arabica coffee prices almost doubled between October 2013 and November 2014 from 122 to 227 US cents per pound. Aluminum prices fluctuated heavily in 2008 and 2009 ranging from 1,400 to more than 3,000 US Dollar per ton (IMF Primary Commodity Prices). This suggests that a 100 percent price change in a year might lead to sizable impacts upon the current account (up to 6 percentage points relative to GDP) and GDP growth (between 4 and 12 percent).

Commodity price developments are correlated. Commodity-dependent countries are therefore often impacted by high (or low) prices on the export and import side at the same time. The results of randomized combinations of commodity import and export prices show that aggregate macroeconomic effects on real GDP are negative on average. However, the magnitude of these effects differs between the three countries. Magnitudes are driven by the economic structure of these economies, particularly their trade patterns as well as the production processes in the export commodity sector. Most strongly affected by positive and negative shocks is Ethiopia. The other two countries have the ability to counterbalance effects on the import side with income increases from exports to a certain degree, particularly due to the larger share of their export commodity in total exports.

A central conclusion is that these commodity-dependent SSA countries can generally not benefit from positive demand shocks through commodity export price increases as they correspond with negative supply shocks through increased import prices with the latter shocks dominating. This highlights that commodity dependence is not just a development problem at the export side but that it is interlinked with commodity import dependence. Given positive correlation of commodity prices and high commodity import dependence, in the short term countries that are more strongly dependent on commodity exports may even better deal with this volatility at a macroeconomic level. However, relying on this counterbalancing effect is only a myopic and highly risky answer to the problems of commodity dependency.

More important than macroeconomic effects are distributional outcomes in our model, however. These results are related to the distribution of potential windfall profits from the export commodity sectors and the dependence of different households on oil and food imports. In Burkina Faso, the large share of windfall profits attributed to small holder farmers causes an overall positive effect in subsistence household incomes in response to commodity price increases. This outcome is not present for subsistence households in the other two countries, as import price shocks are not sufficiently balanced by export earnings, particularly in Mozambique. In general, the participation of subsistence households in the production of the export goods and the share of profits that these producers receive, determines their potential benefits if prices rise and risks if prices decline.

For the economy as a whole the repatriation of profits from commodity exploitation is a thread that is particular common in oil and mineral sectors, as shown for the case of Mozambique. This is not a major concern in the cotton and coffee sectors that is dominated by domestic capitalists that also own businesses in the modern sector and hence consume and invest most of their profits locally. Moreover, the inclusion of labor flows between modern and subsistence sectors that are affected by import and export price changes, acknowledges the high level of underemployed labor force in these countries that drives model results and is a crucial development concern in LDCs.

Although the countries analyzed in this paper have undergone significant economic transition in recent years, the potential effects of commodity price fluctuation have not been curbed. The capital intensive mining of gold in Burkina Faso that has overtaken cotton as the number one export sector and the mega projects in coal, natural gas and heavy oil sands that have been established in addition to aluminum in Mozambique, are similarly vulnerable to global commodity price volatility. Only in Ethiopia an industrialization process has been underway that reduced global commodity price vulnerability on the export side. This is seen in the share of manufactured exports having increased from 5.1 to 11.1 percent between 2005 and 2013 (compared to lower levels of 7.6 and 8.5 percent respectively in Burkina Faso and Mozambique in 2013; UNCTADstats).

Commodity import dependence remains on a persistently high level in all three countries, however. Given the structural dependence on specific import commodities, the vulnerability to global commodity price volatility will remain a major concern for these countries even if they should succeed in export structure diversification. Counter-measures in the short run may include price stabilization funds for food and/or oil imports, while medium to long run solutions may aim for supporting food production to ensure local food availability as well as developing alternative energy sources at a national and regional level.

On the export side, besides furthering diversification and particular industrialization of the economy, other policy responses on the national level range from: price stabilization schemes for smallholders as existing in Burkina Faso, mechanisms to ensure higher shares from export prices for producers in the context of regulated negotiations between associations or commodity exchanges as existing in Ethiopia, national commodity funds to deal with price volatility and related risks for local actors, and the appropriate taxation of large-scale commodity projects. Further, diversification of end markets towards regional markets and particularly domestic markets and hence local value addition are important strategies to reduce export dependence.

On the global level, price stabilization measures would, first, include the regulation of commodity derivative markets as global commodity prices are determined by trading strategies of commercial and financial actors on these markets. Financialisation of these markets has supported co-movement of diverse commodity prices, distorting prices from fundamental factors, particularly in the short run. Second, global counter-cyclical financing facilities to mitigate income shocks from commodity price movements are needed (Griffith-Jones/Ocampo 2007; Nissanke/Kuleshov 2012). Such financing facilities could ensure financing of national price stabilization schemes, particularly in the context of longer low-price periods, and policy space for counter-cyclical macroeconomic policy more generally (Staritz et al. 2015b). These global measures would be crucial to stabilize economic development in commodity-dependent economies and enable diversification and structural transformation.

Our simulation approach has highlighted potential impacts of commodity price dependence upon the macroeconomy of LDCs. While further research is needed in order to gain a more detailed understanding of the impacts on individual countries, the main message is that the overall macroeconomic and distributional effects of commodity price booms critically depend on the economic structure of a country.

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Appendix

A1. Details on SAM construction

The three country SAMs are based on existing research that also served as databases for GTAP 8. All SAMs are freely available via the country details in the GTAP Africa 2 database. However, documentation is available only for Ethiopia (EDRI 2009).

Table 1A: Original SAM details

Country	Base Year	Author(s) / Organization	Dimensions (industries x commodities)	Sources
Ethiopia	2005/06	EDRI (2009)	47 x 93	EDRI website
Burkina Faso	2005	Balma (2012)	75 x 133	GTAP, Africa 2 Data Base
Mozambique	2007	Arndt/Pauw/Thurlow (2012)	54 x 56	GTAP, Africa 2 Data Base

All original SAMs are balanced and were constructed in a 'Make and Use' form, i.e. they include a make matrix (V) as well as a use matrix (U) and therefore use a commodity-by-industry approach with different dimensions. For the aggregated version, the original SAMs were transformed to a symmetric, commodity-by-commodity input output structure, based on the 'Model B' transformation described in Eurostat (2008, 347-353).

The SAM includes four sectors: modern sector (includes industry and services as well as larger scale and commercial agriculture activities), commodity exports (includes commodities with highest share in total exports), energy provision (includes oil, fuels, gas, electricity, fertilizers), and agriculture/food sector (includes cereals, fruits, vegetables, nuts, oils, tea). All other agricultural commodities are summarized in the modern sector.

For all countries, three households are defined (modern (HH1), subsistence (HH2) and capitalists). HH2 is equivalent to rural poor households and it is assumed that these households receive their income from the agricultural sector and, where relevant, the export sector. HH1 and HH2 have savings propensities of zero and therefore consume all their after-tax income. The capitalists are also consuming, but are the only household group that saves. Public investments are included in government expenditures. Official transfers are added to government income and official transfers from government to households were netted with direct taxes. Moreover, transportation margins are defined as intermediate services and included in the modern sector. Exports serve as residual to balance SAMs if necessary.

In Burkina Faso, the cotton sector was a combination of three single commodities. Thus, the intermediate flow from cotton grain to cotton ginned is excluded in our SAM. Public investment is estimated based on national statistics. All chemical goods, including fertilizers, are added to the energy provision sector. The original SAM in Mozambique was modified to be consistent with macroeconomic data of the World Bank, the IMF and the National Statistical Office. Additionally, we adjusted the imports into the aluminum sector according to UN Comtrade data and information from Friends of the Earth Mozambique (2012), lifting imports to the export commodity sector from 2 billion to 14 billion Metical or one third of aluminum export value. In Mozambique, only one type of households was included in the original SAM, thus, the expenditure structure of households was added based on the example of Burkina Faso.

A2. Linkage analysis

The linkage analysis underlying Table 5 and Figure 1 is standard. Hirschman (1958) discusses related ideas, and Chenery (1960) provides an original discussion. See Miller and Blair (1985) for a book treatment. Here, we briefly summarize the determination of key sectors. To begin, suppose A is the matrix of input requirements with elements a_{ij} . Then $L = (I - A)^{-1}$ is the Leontief inverse or matrix of multipliers with elements l_{ij} . Forward linkages are defined as the row sums ($f_i = \sum_{j=1}^n l_{ij}$); and backward linkages as the column sums ($b_j = \sum_{i=1}^n l_{ij}$) of the Leontief inverse. The *average intensity* is the sum of total requirements coefficients relative to the number of sectors: $\alpha = n^{-1} \sum_{j=1}^n l_{ij} \sum_{i=1}^n l_{ij}$. Intersectoral comparisons can be made by scaling each backward and forward linkage by α , to get

$$F = \frac{1}{\alpha} \sum_{j=1}^n l_{ij} \quad (\text{A1})$$

$$B = \frac{1}{\alpha} \sum_{i=1}^n l_{ij}, \quad (\text{A2})$$

as indices of forward (F) and backward (B) linkages, respectively. Values above unity indicate strong linkages, below weak ones. Table 5 reports these indices for the three countries.

We can further define the *multiplier product matrix*

$$M = \frac{n}{\alpha} \begin{bmatrix} f_1 b_1 & f_1 b_2 & \cdots & f_1 b_n \\ f_2 b_1 & f_2 b_2 & \cdots & f_2 b_n \\ \vdots & \vdots & \ddots & \vdots \\ f_n b_1 & f_n b_2 & \cdots & f_n b_n \end{bmatrix}, \quad (\text{A3})$$

where each entry m_{ij} describes sectoral interaction through a combination of the relevant backward and forward linkages. Figure 1 shows the resulting "economic landscape" for the four sector aggregation of the three countries.

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