Global Oil Prices and Local Food Prices: Evidence from East Africa

Brian M. Dillon and Christopher B. Barrett

It is widely believed that oil prices impact food prices in developing countries. Yet rigorous evidence on this relationship is scarce. Using maize and petrol price data from east Africa, we show that global oil prices do affect food prices but primarily through transport costs, rather than through biofuel or production cost channels. We find that global oil prices transmit much more rapidly to the pump and then to local maize prices than do global maize prices, suggesting that the immediate effects of correlated commodity price shocks on local food prices are driven more by transport costs than by the prices of the grains themselves. Furthermore, we present suggestive evidence that, for markets furthest inland, changes in world oil prices have larger effects on local maize prices than do changes in world maize prices.

Key words: African development, agricultural markets, energy markets, food price volatility, price transmission.

JEL codes: F15, O13, Q11.

The global food price crises of 2008 and 2011 drew widespread attention to the effects of commodity price shocks on poverty and food security in the developing world. In the ongoing debate over the causes of these price spikes, one prominent thread emphasizes the role of oil prices (Abbott, Hurt, and Tyner 2008; Headey and Fan 2008; Mitchell 2008; Rosegrant et al. 2008; Baffes and Dennis 2013; Wright 2014). Yet there is a notable absence of careful empirical analysis of the links between global oil markets and the food prices that most affect the poor, that is, those in markets within developing countries. How and by how much do global crude oil price shocks affect local food prices, particularly in countries with high levels of subsistence food production?

This article addresses that important question for maize markets in the four major east African economies: Ethiopia, Kenya, Tanzania, and Uganda. These markets are ideal for studying the oil-food link in developing economies. Maize is the primary staple food in east Africa; the region is distant from major maize exporters so that shipping costs are a potentially important factor in border prices; and transport infrastructure is relatively under-developed so that fuel costs related to overland trade are potentially significant.

Oil prices can affect maize prices through three main channels. First, higher oil prices can increase the cost of farm inputs such as

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inorganic fertilizer and fuel for tractors or pumps. Second, higher global oil prices can directly affect global maize prices, perhaps by stimulating demand for corn to convert to biofuel, with global maize prices then transmitted to local markets through trade. Third, oil price increases can drive up transport costs, which affect the prices of all traded commodities, food grains included.

The first channel is of second order importance for the study countries, both because of the minimal roles of fuel-powered machinery and inorganic fertilizer in production, and because long-run price trends are tied to world markets (though not always in accordance with the Law of One Price [LOP]; see below). For these economies, changes in production costs may affect profits, output levels, and short-run prices, but the cost of oil-based inputs to production should not drive long-run equilibrium prices. To the extent that we can measure the prices of relevant oil-based inputs—in this case, fertilizer—this is indeed what we find. Once we control for changes in global maize prices, which capture the direct effects of global oil price shocks on production costs in the world's major maize producing countries, we find a negligible role for fertilizer prices in local maize price determination (Supplementary Appendix A).[1]

The second channel rests on the premise that there is a structural link between oil prices and maize prices, related to biofuels or to some other mechanism. This topic has received substantial attention since the passage of the ethanol mandate in the US Energy Policy Act of 2005. Indeed, the two price series are indisputably positively correlated. In our data the correlation coefficient between nominal global oil and maize prices is 0.83, and that between inflation-adjusted prices is 0.45. However, the recent literature finds little empirical support for the hypothesis that oil price changes transmit strongly to maize prices on global markets; rather, they seem to share common drivers (e.g., Zhang, Vedenov, and Wetzstein 2007; Zhang et al. 2009, 2010; Gilbert 2010; Serra et al. 2011; Enders and Holt 2012, Zilberman et al. 2013). We estimate a number of models relating oil and maize prices on global markets, and find no evidence of cointegration (Supplementary Appendix B). We therefore do not focus on this channel. However, in interpreting results we consider the case of correlated increases in global oil and maize prices. In this sense our approach is conservative. Any undetected links through biofuels would only amplify the effects that we find.

We focus on the third channel, the link through transport costs. Transport costs loom large in African markets because of the low value-to-weight ratio of grains, rudimentary transport infrastructure dependent primarily on lorries (i.e., trucks), and the importance of international shipping costs in border prices. Although home production is widespread, significant volumes of maize are traded in each of the study countries. The food supply to urban consumers relies heavily on grain shipments from breadbasket regions and ports of entry. As we show, global oil prices exert considerable influence on sub-national maize market prices, through their effects on fuel prices.

Using a newly assembled data set of monthly, average prices of maize and petrol (at the pump) from 17 subnational markets for the period 2000–2012, we estimate the pass-through effects on local maize prices of changes in the world market prices of oil and maize. Our empirical approach involves stepwise estimation of error correction models, which are validated by Johansen cointegration tests (Johansen 1991, 1995).

We have two main results and also report a third intriguing finding that requires further study. First, we find an important role for global crude oil prices in determining maize prices in local markets within east Africa. On average, a 1% increase in global oil prices leads to a maize price increase of 0.26%, even in the absence of changes in global maize prices or in the exchange rate. This finding is remarkably stable across study markets; 15 of the 17 pass-through rate estimates lie in the range 0.10%–0.41%. In comparison, the average elasticity of the local maize price with respect to global maize price is 0.42, with considerably more dispersion among markets. When global oil and maize prices co-move, the elasticity of local maize prices is 0.68. These estimated rates of price transmission are greater than those in much of the

[1] See Supplementary Appendix A for details. Little of the maize grown in east Africa is produced using tractors or irrigation pumps. Kenya is the only country with widespread fertilizer application during the study period. In Supplementary Appendix A, we show that maize prices in Kenya do not respond to changes in the price of fertilizer. We also show that, after controlling for the global prices of maize and oil, global fertilizer prices are not an important determinant of domestic prices of maize or fuel in any of the study countries.

current literature, which do not explicitly account for transport costs (Benson, Mugarura, and Wanda 2008; Abbott and Borot de Battisti 2011; Baltzer 2013).

Second, we find that oil price shocks transmit much more rapidly—to the pump and then to local maize prices—than do global maize price shocks. On average, global maize prices take 61% longer to transmit to local food prices than do global oil prices. This is likely because fuel is an imported good and international trade is the only way to clear the market. Maize, in contrast, is produced by tens of millions of spatially dispersed farmers, allowing for local supply responses and consumption out of stocks that dampen the speed of price transmission. An important implication is that when oil prices and maize prices co-move on global markets, as they often do, the immediate effect on food prices may be due more to changes in transport costs than to changes in the global prices of grains.

Third, we find suggestive evidence that in the markets that are farthest from ports of entry, the elasticities of local maize prices with respect to global oil prices are equal to or greater than those with respect to global maize prices. In general, the estimated elasticity of local maize to global oil is increasing in distance from the domestic port-of-entry. This finding is based on data from only 17 markets, however, and so cannot be considered robust. Nevertheless, the suggestion that food prices in inland markets may respond more to transport fuel price variation than global grain price variation underscores the importance of variable transport costs in understanding food security in landlocked areas.

These findings contribute to a number of strands in the literature. There is a large body of research on transport costs, but the emphasis is on the fixed cost components of transport—roads, railways, and so forth. To our knowledge, this is the first article to make use of variable transport costs in a study of food price determination in the developing world.[2] The lack of rigorous research on this topic is likely due to the scant availability of spatially disaggregated data on variable transport costs (World Bank 2009, 175), which we assembled from a wide range of sources.

More broadly, our findings add to the literature on food security and vulnerability to shocks for rural households in poor countries (Baulch and Hoddinott 2000; Dercon 2002; Barrett, Sherlund, and Adesina 2006). While there is substantial work on the impacts of weather, health, and other shocks on food production and welfare, much less is known about the links between the prices of non-food commodities and local food prices. It is striking that long run equilibrium maize prices in the furthest inland markets are influenced more by global oil prices than by global maize prices or local conditions. Because poor households in east Africa, even in agricultural areas, are overwhelmingly net food buyers (Barrett 2008; Ivanic, Martin, and Zaman 2012), this suggests that oil price fluctuations represent a more significant threat to welfare than has been previously documented.

Finally, this article connects to prior work on commodity price dynamics and global-to-local price transmission in Africa (Ardeni and Wright 1992; Deaton 1999; Baffes and Gardner 2003; Minot 2010). As Deaton states, "the understanding of commodity prices and the ability to forecast them remains seriously inadequate. Without such understanding, it is difficult to construct good policy rules" (1999, 24). This concern still applies today, as variable and unpredictable global commodity prices remain an important agenda item for policymakers and researchers.

Data

Figure 1 shows the location of the 17 markets for which we could match fuel and maize price series. All are urban areas, but of varying size and remoteness. The port-of-entry (POE) markets are Mombasa, Kenya; Dar es Salaam, Tanzania; Kampala, Uganda; and Addis Ababa, Ethiopia. We focus on the period 2000–2012, with slight variation in the coverage period due to data limitations.

We use monthly average nominal prices for all markets. Higher frequency data were not available. Global prices are from the World Bank Global Economic Monitor. Crude oil prices (nominal \$/barrel) are the average spot prices for major world markets, and maize prices are nominal \$/metric ton for number 2 yellow maize in the US Gulf.

[2] See Storeygard (2012) for a study that incorporates fixed and variable transport costs.

Figure 1. Study market locations

Wholesale maize prices for markets in Kenya are from the Famine Early Warning System (FEWS). Average wholesale maize prices for Tanzania were provided by the Ministry of Agriculture, via the International Growth Center (IGC). Wholesale maize prices for Ethiopia are from the Ethiopia Grain Trade Enterprise. Retail maize prices for Uganda markets are from the Regional Agricultural Trade Intelligence Network

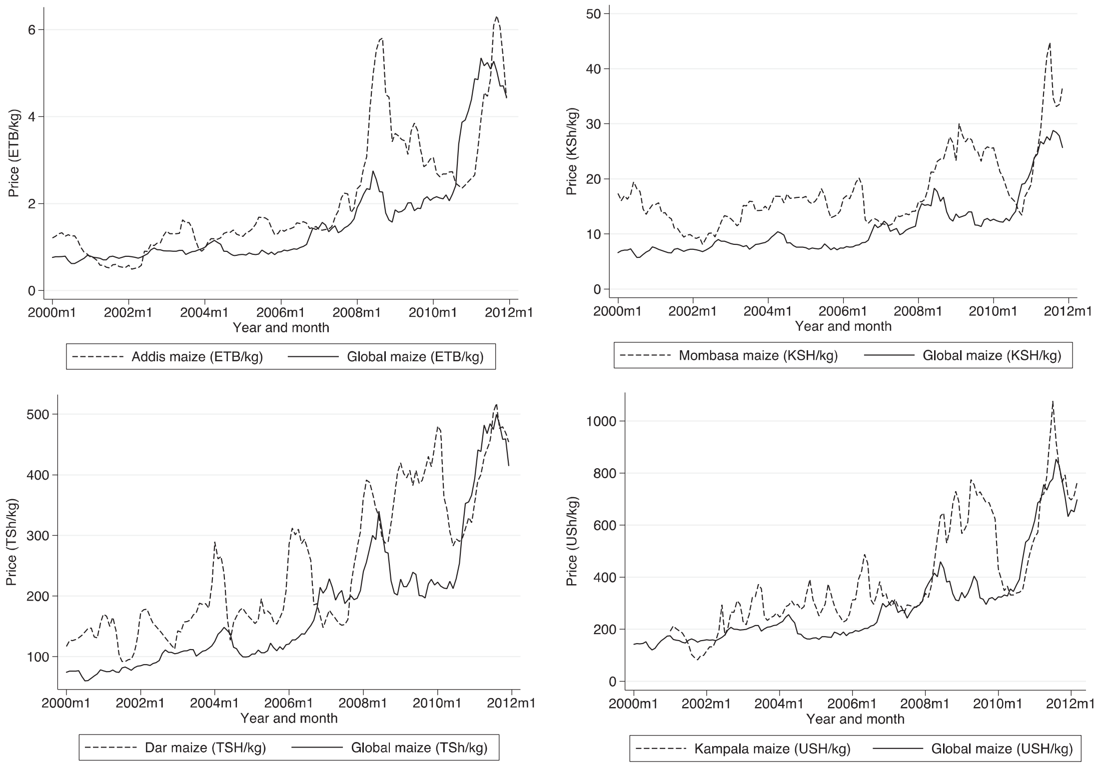

Figure 2. Global maize prices and maize prices in POE markets (nominal), 2000–2012

(RATIN) of the East Africa Grain Council (wholesale prices were not available).[3] US dollar exchange rates for each country are from the International Monetary Fund (IMF).

For subnational fuel prices, we use petrol prices at the pump.[4] The market-specific mandated prices in Ethiopia, along with the exact dates of all price changes, were provided by the Ministry of Trade and Industry. The national bureaus of statistics in Kenya and Uganda provided their respective monthly average retail prices of petrol.[5] Pump prices for Tanzania markets were provided by the Bank of Tanzania and IGC.

In figure 2, we plot the domestic POE maize prices against global maize prices.[6] For ease of comparison, global prices are expressed in local, nominal units. Intra-annual seasonality related to the harvest cycle is clearly visible. Because a key component of the cointegrating vector—the oil price—is not shown on the graph, it is not easy to see how the long-run trajectories of prices in each market track the shifts in global prices. However, in Supplementary Appendix C we show that all four study countries are engaged in at least some degree of cross-border maize trade in every year for which we have data, so that trading volumes are at the interior.

Figure 3 shows the time path of POE fuel prices plotted with global oil prices. It is clear that each POE-global pair closely co-moves, with changes in the POE price tending to lag global price changes. Infrequent updating of

[3] To accommodate missing values in the Uganda RATIN series, we predict prices using least squares estimates based on regressions of RATIN prices on Uganda maize prices from non-study markets that are available from other sources, such as FEWS, Uganda FoodNet, and the Food and Agriculture Organization of the United Nations. Details available upon request. We use a similar procedure to replace a small number of missing prices in the other countries.

[4] Diesel prices would arguably be better but are not as widely available. Petrol and diesel prices are highly correlated in those markets for which we have both.

[5] In Kenya, we could assemble fuel price data from Nakuru but not from Eldoret, and vice versa for maize. These cities are proximate and are the two main urban areas of Rift Valley Province in Kenya. We merge them into a synthetic series, using Eldoret maize prices and Nakuru fuel prices.

[6] Farmers in study countries typically grow white maize, but we only have global prices for yellow maize. This is of little consequence, as the prices are highly correlated.

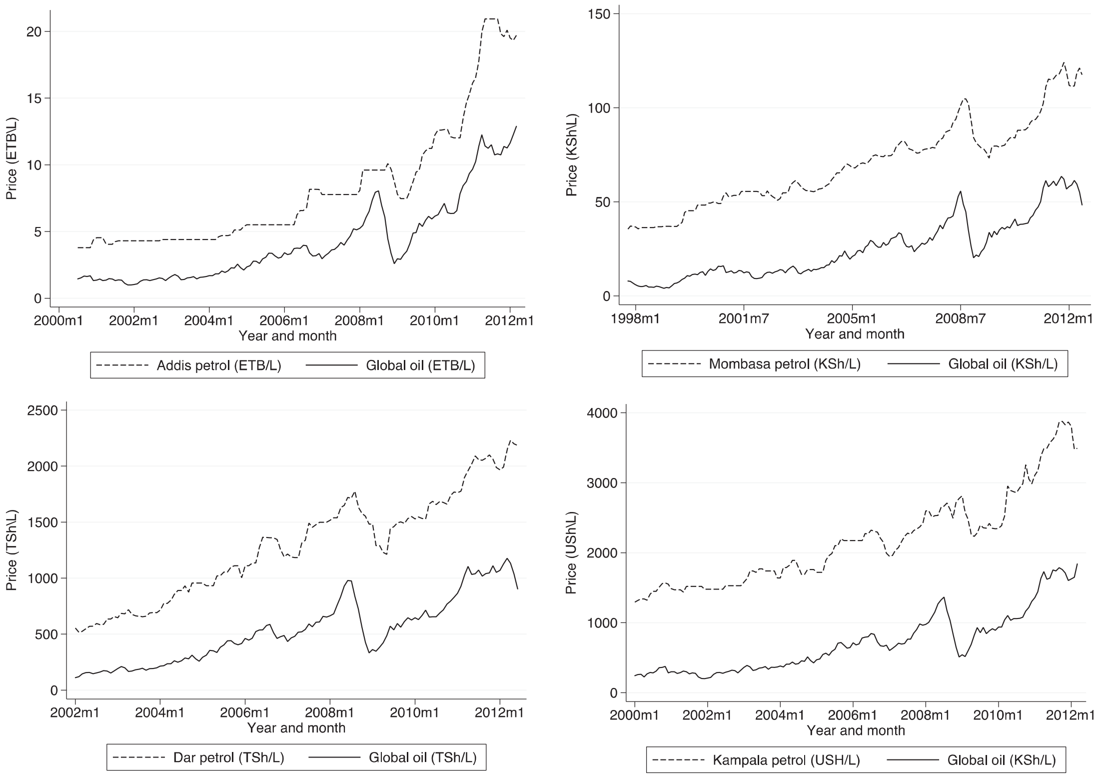

Figure 3. Global oil prices and petrol prices in the POE markets (nominal), 2000–2012

the Addis Ababa petrol price, a consequence of government-mandated pricing, is clear in the top left panel.

Additional descriptive and background details, covering production, trade, and policies for both maize and oil, are provided in Supplementary Appendix C.

Empirical Approach

We do not model a causal relationship between the prices of oil and maize on global markets, because Johansen rank tests indicate that global oil and global maize prices are not cointegrated (Supplementary Appendix B). This is consistent with numerous recent papers that find no strong causal link from oil to maize on world markets (Zhang, Vedenov, and Wetzstein 2007; Zhang et al. 2009, 2010; Gilbert 2010; Serra et al. 2011; Enders and Holt 2012; Zilberman et al. 2013). Although it remains possible that a causal relationship exists between these markets (de Gorter et al. 2013), we proceed under the conservative assumption that the global oil price does not directly impact the global maize price. If global oil price shocks do cause global maize adjustments (because of biofuels, or otherwise), our estimates of cumulative pass-through represent lower bounds on the true impact of oil prices on maize prices in east Africa.

Our empirical strategy involves stepwise estimation of error correction models treating the larger market price as weakly exogenous to the smaller market price.[7] All of the nominal price series in this study are difference stationary (Supplementary Appendix B). Following a large price transmission literature, we allow for asymmetric adjustment to price increases and decreases at each stage (e.g., Borenstein, Cameron, and Gilbert 1997; von Cramon-Taubadel 1998). There are various reasons to expect transmission asymmetries, including substitution possibilities between fuels, firm-level market power, fragmented wholesale distribution systems (Peltzman 2000), government policy

[7] This procedure is only sequential in the sense that cumulative pass-through rates are inferred from the average pass-through rates in each stage of price transmission. We do not use predicted values from one step in the estimation of the next.

interventions, the asymmetrical effects of food aid imports, and infrastructural bottlenecks such as limited port capacity (Meyer and von Cramon-Taubadel 2004; Admassie 2013). These effects cannot be separately identified in our data. But because our interest is in the pass-through effects of long-run price *increases*, it is important to allow for asymmetries to ensure that we do not average over the responses to price increases and decreases.

Our approach rests on four identifying assumptions. The first is that the global markets for both maize and oil are exogenous to prices in the study countries. The second is that there is no feedback from maize prices to fuel prices within study countries, rendering petrol prices weakly exogenous to maize prices. This is a mild assumption given the absence of biofuel production in the region and the small share of maize in gross freight haulage. The third assumption is that global prices are transmitted to local markets via the POE, so that the POE prices are weakly exogenous to interior market prices. This assumption follows from the first assumption and the continuity of international trade in both commodities (Supplementary Appendix C). While this may be a simplification in the months immediately after harvest, it is surely a benign assumption in the medium term because trade with international markets, and therefore the price-setting mechanism, is mediated primarily through the POE. The fourth assumption is that the exchange rate is weakly exogenous to oil and maize prices over the study period. In the long run this may not hold, as exchange rates are likely endogenous to commodity price changes. However, we include monthly exchange rates in the long-run equations of all models linking global prices to domestic prices, a specification choice that is validated by Johansen (1995) tests. Also, in Supplementary Appendix D we provide evidence of weak exogoneity of exchange rates.

Finally, in regard to the multistep estimation procedure, we believe it is important to estimate the POE-global price link in a first stage because this allows us to measure the effects of country-specific tariffs and import policies. Then, equations linking the POE prices to each subnational market allow for distance, infrastructure differences, and possible local market effects to differentially affect the rate at which global prices transmit within national markets.[8] Estimating the entire system simultaneously would make it difficult to interpret the cointegrating vectors, and would require that we potentially misspecify the short-run equations by imposing symmetry.[9]

Step 1. Global-POE Price Linkages

For all four countries, rank tests based on Johansen (1991, 1995), indicate a single cointegrating vector between global oil prices, POE fuel prices, and the exchange rate, with a constant in the long-run equation (Supplementary Appendix E). Therefore, for each country we estimate the following two-stage asymmetric error-correction model (ECM), using the Schwarz Bayesian criterion (SBC) to choose the lag length (which is two periods, in all cases):[10]

$$(1) \qquad F_t^{POE} = \alpha + \beta_1 F_t^G + \beta_2 ER_t + \varepsilon_t$$

$$(2) \qquad \Delta F_t^{POE} = \delta_0 ECT_t^{neg} + \delta_1 ECT_t^{pos} + \sum_{k=1}^{K} \Big\{ \delta_{3k-1} \Delta F_{t-k}^{POE} + \delta_{3k} \Delta F_{t-1}^{G} + \delta_{3k+1} \Delta ER_{t-k} \Big\} + \nu_t$$

where F_t^{POE} is the POE fuel price in month t, F_t^G is the global oil price, ER_t is the US dollar exchange rate (local currency over USD), and ε_t and ν_t are statistical error terms (Engle and Granger 1987).

Equation (1) represents the cointegrating vector, that is, the long run equilibrium relationship between the variables. In general, the average elasticity of price p_j to price p_i, denoted η_{ji}, is calculated as $\hat{\eta}_{ji} = \frac{\hat{\beta}_i \bar{p}_i}{\bar{p}_j}$, where $\bar{p}_k$ is the average of price k over the observations used in the regression, for $k \in \{ij\}$, and $\hat{\beta}_i$ is the estimated coefficient on price i in the relevant regression.[11] For each study country,

[8] For multiple reasons, we do not control for policy changes with dummies for possible structural breaks. First, the time series are relatively short, and many policy changes (e.g., fuel price caps) occurred near the start or end of the study period. Second, there are few policy changes that can be confidently assigned to specific months. Third, many relevant policies are endogenous to market conditions.

[9] We are not aware of any papers that estimate a vector error correction model as a single system while allowing for asymmetry in the short-run equations. Developing such a method here would take us well beyond the scope of this article.

[10] Out of concern for overfitting, we do not allow for thresholds in the ECM.

[11] We prefer the specification in levels rather than logs so that we can interpret coefficients in terms of price spreads rather than

we estimate the long-run elasticity of the POE fuel price with respect to the global oil price by setting $p_j = F^{POE}$ and $p_i = F^G$ in this formula, and using the estimated coefficient from equation (1).

Equation (2) captures short-run dynamics. The error correction term, ECT_t, is the residual from equation (1), which measures period $t-1$ deviations from the long run stationary relationship. The *neg* and *pos* superscripts indicate the sign of the residuals (the variable $ECT_t^{neg} = ECT_t$ if $ECT_t < 0$, equals 0, equals 0 otherwise, and complementarily for ECT_t^{pos}). Estimates $\hat{\delta}_0$ and $\hat{\delta}_1$ are speed-of-adjustment parameters for negative and positive deviations from the long-run equilibrium, respectively. Both should be negative.

We estimate a similar model for maize. The primary modification is that we include the global oil price in the maize ECM system, to allow for changes in shipping costs to impact the margin between POE maize prices and global maize prices:

$$(3) \qquad M_t^{POE} = \alpha + \beta_1 M_t^G + \beta_2 F_t^G + \beta_3 ER_t + \varepsilon_t$$

$$(4) \qquad \Delta M_t^{POE} = \delta_0 ECT_t^{neg} + \delta_1 ECT_t^{pos} + \sum_{k=1}^{K} \Big\{ \delta_{4k-2} \Delta M_{t-k}^{POE} + \delta_{4k-1} \Delta M_{t-1}^G + \delta_{4k} \Delta F_{t-1}^G + \delta_{4k+1} \Delta ER_{t-k} \Big\} + \nu_t$$

where M_t^{POE} is the POE maize price in month t, M_t^G is the global maize price in month t, and other variables are as above.

Maize price transmission is facilitated by near constant (albeit low volume) trade between study countries and international markets. However, other mechanisms besides private trade can serve to exacerbate or attenuate price transmission. For example, parastatal organizations or food aid donors may respond to high domestic prices by sourcing grain on global markets, increasing domestic supply and reducing prices.

Step 2. Within-country fuel price transmission

We expect fuel prices in subnational markets other than the POE to reflect POE fuel prices plus domestic transport costs. Deviations from this relationship—due to supply chain disruptions, localized fuel demand shocks related to seasonality, or other forces—should not persist for long under reasonably competitive conditions. Not surprisingly, Johansen tests clearly indicate the presence of a single cointegrating vector between the POE market price of fuel and the fuel price in each non-POE market in the sample. In all cases, the SBC indicates an optimal lag length of two months in levels (1 month in differences). Accordingly, for each POE–market j pair, we estimate the following ECM:

$$(5) \qquad F_t^j = \alpha + \beta F_t^{POE} + \varepsilon_t$$

$$(6) \qquad \Delta F_t^j = \delta_0 ECT_t^{neg} + \delta_1 ECT_t^{pos} + \delta_2 \Delta F_{t-1}^{POE} + \delta_3 \Delta F_{t-1}^j + \omega_t$$

where F_t^j is the fuel price in market j, in month t, and other terms are as described above.

Step 3. Within-country maize price transmission

The final relationships of interest are those between POE maize prices and maize prices at subnational markets. Here we allow local fuel prices to affect maize price spreads between the POE and other markets. Once again, rank tests show that in all specifications there is at most a single cointegrating vector between POE maize prices, other market maize prices, and other market fuel prices, with an optimal lag of length of two months (in levels). The error-correction framework takes the following form:

$$(7) \qquad M_t^j = \alpha + \beta_1 M_t^{POE} + \beta_2 F_t^j + \varepsilon_t$$

$$(8) \qquad \Delta M_t^j = \delta_0 ECT_t^{neg} + \delta_1 ECT_t^{pos} + \delta_2 \Delta M_{t-1}^{POE} + \delta_3 \Delta F_{t-1}^j + \delta_4 \Delta M_{t-1}^j + \omega_t$$

where M_t^j is the price of maize in market j and all other variables are as before. The hypothesis $H_0: \beta_2 > 0$ captures the expected effect of fuel prices on maize price spreads.

We estimate all of the equations in steps 1–3 using ordinary least squares, to allow for the asymmetric structure (Granger and Lee 1989). If needed, lags are added to the

proportions, and because over such a long period we would prefer not to impose a constant elasticity framework. This turns out to be inconsequential, because log-log specifications give similar elasticity estimates.

Table 1. POE Fuel and Global Oil, ECM Results

	Ethiopia	Kenya	Tanzania	Uganda
First stage				
Global oil ($/bl)	0.053***	0.621***	8.667***	14.507***
	0.004	0.014	0.451	0.531
R^2	0.955	0.94	0.96	0.94
Pass-through elasticity (oil)	0.38	0.463	0.435	0.383
Second stage				
L.ECT^{neg}	−0.206***	−0.171***	−0.483***	−0.310***
	−0.055	−0.0366	−0.0854	−0.077
L.ECT^{pos}	−0.105***	−0.107***	−0.156**	−0.179***
	−0.038	−0.0317	−0.0656	−0.0487
R^2	0.5	0.589	0.345	0.25
F test: ECM asymmetry (*p*-value)	0.14	0.121	0.001	0.135
N	141	177	126	147
Mean POE price (Local/L)	8.15	69.55	1283	2176

Notes: Dependent variable in first stage is the nominal price of retail petrol in the POE market; first-stage results are known to be super-consistent; dependent variable in second stage is the change in nominal POE fuel price. Single asterisk (*) denotes significance at the 10% level, double asterisk (**) denotes significance at the 5% level, and triple asterisk (***) denotes significance at the 1% level. Regressions span 2000–2012 for KY and UG, 2000–2011 for ET, 2002–2011 for TZ; ECT is the residual from the first stage regression of POE price on global price and a constants; regressions include the exchange rate.

second-stage equations to ensure white noise residuals (Enders 2010).

Results

In this section, we present the results of estimation steps 1–3 in sequence. Full results of all regressions are available in Supplementary Appendix F. To summarize, we find that domestic prices for both commodities are integrated with world prices, though cross-border elasticities are far below one so the LOP does not hold. Oil prices significantly affect the spread between global maize prices and POE maize prices, but in all stages the oil/fuel price plays a much greater role in long run price determination than in short run dynamics (this is viewable in the full results of the second stage regressions, in Supplementary Appendix F). Within country, the LOP holds for all petrol markets and most maize markets, and the local fuel price significantly impacts the spread between maize markets in all countries other than Ethiopia.

Global-POE price transmission

Table 1 shows the key variables from estimates of equations (1) and (2), for all countries. The key findings in the top panel are summarized in the average pass-through elasticities for oil price changes. The estimates are remarkably similar across countries: on average, a 1% increase in the price of oil on world markets leads to an increase in the POE petrol price of 0.38%–0.46%. The remainder of the variation is accommodated by exchange rate depreciation (full results of these and other regressions are in Supplementary Appendix F).

The bottom panel of table 1 shows the second-stage estimates of equation (2). All coefficient estimates have the expected sign, when significant. Adjustment back to the long run equilibrium is not instantaneous, but is fast on average, with monthly adjustment rates ranging from 17% to 48%. Price increases transmit faster than price decreases, though only in Tanzania is the difference between positive and negative adjustment statistically significant at 10%.[12] This is consistent with import bottlenecks, such as port constraints, foreign exchange constraints, or contracting lags, and also with imperfect competition in which importers adjust prices upward more quickly than downward.

[12] If asymmetries are present but at less than monthly frequency, they will be difficult to detect (von Cramon-Taubadel 1998). The fact that we find any statistically significant asymmetries, and that the level differences are in many cases substantial, suggests that the underlying asymmetries may be even more severe than they appear in our data.

Table 2. POE Maize, Global Maize, and Global Oil, ECM Results

	Ethiopia	Kenya	Tanzania	Uganda
First stage				
Global maize ($/mt)	0.0115***	0.026*	0.593***	1.201***
	−0.00257	−0.0137	−0.191	−0.414
Global oil ($/bl)	0.0129***	0.096***	0.367	1.546**
	−0.00445	−0.0298	−0.406	−0.779
R^2	0.721	0.604	0.692	0.682
Pass-through elasticity (maize)	0.823	0.215	0.352	0.467
Pass-through elasticity (oil)	0.356	0.306	0.0843	0.235
Second stage				
L.ECT^{neg}	−0.170***	−0.104*	−0.129***	−0.177**
	−0.0497	−0.0579	−0.0461	−0.0747
L.ECT^{pos}	−0.163***	−0.151***	−0.107**	−0.133**
	−0.0416	−0.0506	−0.0463	−0.052
R^2	0.35	0.18	0.23	0.19
F test: ECM asymmetry (p-value)	0.905	0.539	0.732	0.613
N	144	143	144	135
Mean POE price (Local/Kg)	2.039	17.54	244.6	394.4

Notes: Dependent variable in first stage is the nominal price of maize in the POE market; first-stage results are known to be super-consistent; dependent variable in second stage is the change in nominal POE maize price. Single asterisk (*) denotes significance at the 10% level, double asterisk (**) denotes significance at the 5% level, and triple asterisk (***) denotes significance at the 1% level. Regressions span 2000–2012 for KY and UG, 2000–2011 for ET, 2002–2011 for TZ; ECT is the residual from the first stage regression of POE price on global price and a constants; regressions include the exchange rate.

Table 2 shows estimates of equations (3) and (4), the error correction model linking global and POE maize prices. Pass-through elasticities for maize exhibit greater heterogeneity than did the analogous POE petrol–global oil elasticities, ranging from 0.22 in Kenya to 0.82 in Ethiopia. This is consistent with between-country variation in the degree of government intervention in maize markets, as well as differential responses by domestic producers or variation in food aid responses. The LOP does not hold across the border, as none of the pass-through elasticities approach unity. This is not altogether surprising, as the LOP is a sharp prediction based on an assumption of perfectly competitive spatial equilibrium in the presence of trade (Barrett 2001; Fackler and Goodwin 2001). Various government interventions in food markets (see Supplementary Appendix C), many of them endogenous to global price movements, as well as exchange rate adjustments and variable costs of commerce, can all partially offset nominal price transmission even in otherwise competitive markets. Pass-through elasticities of POE maize with respect to global oil prices are substantial, lying in the range 0.08–0.36, even after accounting for the direct impact of maize price changes. In Kenya, by far the biggest maize importer in the study, a 1% increase in global oil prices exhibits greater upward pressure on POE maize prices (0.31%) than does a 1% increase in global maize prices (0.22%), underscoring the importance of international shipping costs for the pricing of bulk grains sourced from global markets.

In the second stage ECM results, the error correction terms are highly statistically significant during periods of both negative and positive deviation from long-run equilibrium, though in both cases the speeds of adjustment are lower than those for oil price increases. In all cases, asymmetric adjustment can be rejected. Adjustment results are remarkably consistent: out-of-equilibrium global maize prices are absorbed into the POE price at a monthly rate of 10%–17%, persisting up to or beyond the arrival of the next harvest. Coefficient estimates on lagged differences in global oil prices are not significant in any of the equations (Supplementary Appendix F). This suggests that, at the global-POE level, changes in transport costs matter more for the long-run equilibrium than for short-run price dynamics, a finding consistent with forward contracting on global grain markets.

Within-country petrol price transmission

Table 3 shows the estimates of equations (5) and (6), linking fuel prices in subnational markets to the POE fuel price. Fuel markets are very well integrated within the study countries. The β coefficient estimates from equation (3) are all very close to unity, as are the estimated pass-through elasticities. This is clear empirical support for the LOP in fuel markets, which is expected given that ports-of-entry are the sole domestic sources of liquid transport fuels in each country.

In the second stage estimates, we see that POE price increases transmit faster than POE price decreases in all markets. We can reject symmetry at 10% significance in 4 of the 13 cases (with a fifth *p*-value of .104). Faster pass-through of price increases than decreases could be consistent with the existence of structural impediments to moving additional fuel quickly to non-POE markets, or with imperfect competition among fuel distributors. Overall, equilibrium is restored very rapidly. Adjustment rates range from 31% to 74% in Ethiopia, Tanzania, and Uganda. Kenya adjustment rates are slower on average, though still rapid.

Within-country maize price transmission

Table 4 shows the estimates of equations (7) and (8) for each of the sub-national markets. For 9 of 13 markets—those in Ethiopia and Kenya, as well as Arusha, Dodoma, and Mbale—both the point estimates of and the POE maize price pass-through elasticities are close to unity, indicating conformity with the LOP. Within-country maize price elasticities are lower, in the 0.48–0.80 range, for the other four markets in Tanzania and Uganda: Kigoma, Mbeya, Gulu, and Mbarara. It is noteworthy that these are the markets farthest inland (figure 1), and that these four markets also exhibit the largest positive pass-through elasticities with respect to local fuel prices, ranging from 0.29 in Mbeya to 0.76 in Mbarara. In Mbarara, the estimated petrol price elasticity is higher than the POE maize price elasticity, and in Gulu and Kigoma, the estimated petrol price elasticity is approximately two thirds that of the maize price elasticity estimate.

In contrast, petrol price elasticities at Ethiopia markets, Arusha, Dodoma, and Eldoret/Nakuru are below 0.06 in absolute magnitude. In Ethiopia, fuel prices affect maize prices at the border (table 2), but seem to factor little in the price spreads between markets.[13] The outlier in the bottom panel of table 4 is the −0.618 petrol price elasticity in Mbale. Because this coefficient is interpreted with reference to the long run relationship with the POE price, this suggests that increases in transport costs drive down the price of maize in Mbale relative to the price in Kampala. Because of its location near the Kenya border, it is possible that Mbale receives some imports directly, bypassing Kampala. In the bottom panel of table 4, we see that once again that all of the ECT coefficients have the expected, negative sign (apart from the coefficient on $L.ECT_t^{pos}$ in the Mbale equation, which is not significant). Adjustment back to equilibrium is reasonably fast, with rates ranging from 19% to 92% per month, consistent with prior findings for Tanzania maize markets (van Campenhout 2007).

Discussion

To estimate the full impact of a global oil price increase on equilibrium maize prices in east Africa, we combine the estimated cointegrating vectors and short-run adjustment results across price series pairs. Table 5 summarizes the speed-of-adjustment findings by showing the number of months to absorb 80% of a global market price rise. In all four POE markets it takes substantially longer to return to equilibrium after a global maize price rise than it does to return to petrol price equilibrium following a global oil price rise (columns 1 and 3). Likewise, in Tanzania and Uganda, where governments intervene less in fuel markets than in Ethiopia or Kenya, POE petrol price changes transmit more rapidly within the country than do POE maize price changes (compare columns 2 and 4).

The fifth and sixth columns in table 5 show the cumulative speeds of adjustment from global price changes to local maize prices, allowing for simultaneous adjustment. In all but three cases, maize prices converge to new equilibria substantially faster in response to a global oil price shock than to a global

[13] We find this result surprising and believe it may partially be an artifact of the infrequent updating of the mandated fuel prices in the early years of the data.

Table 3. Within-country Fuel Price Transmission, ECM results

	(1) ET Bahir Dar	(2) ET Dire Dawa	(3) ET Mek'ele	(4) KY Kisumu	(5) KY Nairobi	(6) KY Eldoret	(7) TZ Arusha	(8) TZ Dodoma	(9) TZ Kigoma	(10) TZ Mbeya	(11) UG Gulu	(12) UG Mbale	(13) UG Mbarara
First stage													
POE fuel price	1.034***	1.099***	1.060***	0.978***	0.965***	1.002***	1.015***	1.023***	1.114***	1.054***	1.027***	1.012***	1.010***
	0.005	0.004	0.004	0.008	0.007	0.006	0.012	0.009	0.014	0.01	0.008	0.007	0.007
R^2	0.996	0.998	0.998	0.990	0.991	0.993	0.984	0.990	0.980	0.990	0.992	0.993	0.994
Pass-thru elast.	1.013	1.088	1.036	0.969	0.945	0.998	0.988	1.009	0.992	1.000	0.989	1.015	0.989
Second stage													
$L.ECT^{neg}$	−0.626***	−0.309	−0.503**	−0.104	−0.220*	−0.323**	−0.502***	−0.430***	−0.644***	−0.488***	−0.508***	−0.737***	−0.461**
	−0.222	−0.239	−0.243	−0.085	−0.114	−0.134	−0.165	−0.158	−0.182	−0.162	−0.176	−0.224	−0.192
$L.ECT^{pos}$	−0.173	−0.15	−0.187	0.116	0.0741	−0.264**	−0.287*	−0.273	−0.261	−0.323**	−0.000583	−0.404*	−0.11
	−0.17	−0.29	−0.22	−0.105	−0.0992	−0.114	−0.166	−0.201	−0.159	−0.16	−0.15	−0.22	−0.177
R^2	0.311	0.300	0.305	0.218	0.232	0.259	0.262	0.191	0.403	0.163	0.266	0.235	0.149
F test: asymm.	0.076	0.647	0.291	0.104	0.055	0.725	0.253	0.499	0.032	0.428	0.023	0.237	0.154
N (first stage)	141	141	141	177	177	177	126	126	126	126	147	147	147

Notes: Single asterisk (*) denotes significance at the 10% level, double asterisk (**) denotes significance at the 5% level, and triple asterisk (***) denotes significance at the 1% level. All prices in nominal, local currency terms; ECT is the residual from the first stage regressions; second-stage regressions include lagged differences for POE and own-market fuel prices, with number of lags chosen to ensure stationary residuals; "Eldoret" indicates "Eldoret/Nakuru"; full results in Supplementary Appendix.

Table 4. Within-country Maize Price Transmission, ECM Results

	(1) ET Bahir Dar	(2) ET Dire Dawa	(3) ET Mek'ele	(4) KY Kisumu	(5) KY Nairobi	(6) KY Eldoret	(7) TZ Arusha	(8) TZ Dodoma	(9) TZ Kigoma	(10) TZ Mbeya	(11) UG Gulu	(12) UG Mbale	(13) UG Mbarara
First stage													
POE maize price	0.934***	1.085***	1.030***	1.078***	0.978***	1.044***	0.895***	1.010***	0.667***	0.636***	0.493***	1.051***	0.529***
	0.02	0.031	0.024	0.033	0.032	0.044	0.037	0.041	0.053	0.035	0.031	0.059	0.101
Own fuel price	0.001	0.009	−0.014**	0.052***	0.027**	0.003	0.01	0.007	0.090***	0.046***	0.052***	−0.099***	0.122***
	0.006	0.009	0.007	0.012	0.012	0.016	0.009	0.01	0.012	0.008	0.01	0.019	0.029
R^2	0.979	0.961	0.972	0.951	0.934	0.893	0.93	0.931	0.893	0.918	0.898	0.839	0.649
Maize elasticity	0.989	0.925	0.902	1.018	0.925	1.137	0.926	0.999	0.621	0.809	0.659	1.137	0.482
Petrol elasticity	0.005	0.030	−0.046	0.212	0.111	0.014	0.051	0.033	0.443	0.289	0.410	−0.618	0.761
Second stage													
$L.ECT^{neg}$	−0.921***	−0.796***	−0.275*	−0.521***	−0.468***	−0.413***	−0.404***	−0.188*	−0.293***	−0.337***	−0.188*	−0.353**	−0.236**
	−0.268	−0.139	−0.165	−0.16	−0.144	−0.12	−0.123	−0.113	−0.11	−0.1	−0.103	−0.135	−0.104
$L.ECT^{pos}$	−0.381*	−0.397**	−0.273*	−0.510***	−0.320***	−0.341***	−0.419***	−0.385***	−0.313***	−0.419***	−0.164	0.0504	−0.396***
	−0.226	−0.159	−0.156	−0.134	−0.106	−0.0949	−0.117	−0.102	−0.099	−0.101	−0.106	−0.124	−0.0899
R^2	0.379	0.406	0.448	0.327	0.319	0.261	0.285	0.348	0.243	0.354	0.148	0.130	0.443
F test: asymm.	0.143	0.033	0.993	0.955	0.377	0.622	0.925	0.174	0.886	0.553	0.868	0.022	0.209
N	138	138	138	143	143	143	120	120	120	120	131	114	91

Notes: Single asterisk (*) denotes significance at the 10% level, double asterisk (**) denotes significance at the 5% level, and triple asterisk (***) denotes significance at the 1% level. All prices in nominal, local currency terms; ECT is the residual from the first stage regressions; second-stage regressions include lagged differences for all prices, with number of lags chosen to ensure stationary residuals; "Eldoret" indicates "Eldoret/Nakuru"; full results in Supplementary Appendix.

Table 5. Speed of Adjustment to Global Price Increases: Months Required to Complete 80% Pass-through

		Fuel		Maize				
		Global-POE	POE-local	Global-POE	POE-local	Maize Global-local	Fuel-Maize Global-local	Ratio of maize to fuel (global-local)
Country	Market	(1)	(2)	(3)	(4)	(3), (4) simultaneous	(1), (2), (4) simultaneous	
ET	Addis Ababa	7.0	–	8.7	–	8.7	7.0	1.24
	Bahir Dar	7.0	1.6	8.7	0.6	8.8	7.8	1.13
	Dire Dawa	7.0	4.4	8.7	1.0	8.9	10.4	0.86
	Mek'ele	7.0	2.3	8.7	5.0	12.2	12.4	0.98
KY	Kisumu	8.6	13.9	14.7	2.2	15.7	22.2	0.71
	Mombasa	8.6		14.7		14.7	8.6	1.71
	Nairobi	8.6	10.3	14.7	2.6	15.9	14.9	1.07
	Eldoret/ Nakuru	8.6	4.1	14.7	3.0	16.3	13.1	1.24
TZ	Arusha	2.5	2.3	11.7	3.1	13.4	6.1	2.20
	Dar es Salaam	2.5		11.7		11.7	2.5	4.68
	Dodoma	2.5	2.9	11.7	7.7	17.6	10.8	1.63
	Kigoma	2.5	1.6	11.7	4.6	14.7	6.9	2.13
	Mbeya	2.5	2.4	11.7	3.9	14.1	6.9	2.04
UG	Gulu	4.4	2.3	8.3	7.7	14.4	11.9	1.21
	Kampala	4.4		8.3		8.3	4.4	1.89
	Mbale	4.4	1.2	8.3	3.7	10.7	7.5	1.43
	Mbarara	4.4	2.6	8.3	6.0	12.8	10.6	1.21
AVERAGE								**1.61**

Notes: Authors' calculations based on second stage results in tables 1–4; entries show the number of months required for the smaller market price to absorb at least 80% of an increase in the larger market price.

maize price shock. On average, the period needed to absorb a global maize price rise is 1.61 times as long as the period needed to absorb a global oil price rise. While it is not surprising that adjustment speeds are slower for a good that is produced domestically and sometimes subject to government intervention on food security grounds, the magnitude of the difference is striking. The implication is that in the face of correlated increases in global maize and oil prices, short term impacts on food prices in east Africa are driven more by induced changes in transport costs than by the direct pass-through effects of higher grain prices.

Of course, rapid pass-through from oil prices to food prices matters only if the total impact is of significant magnitude. In table 6 we see that it is. The table shows the estimated cumulative pass-through elasticities of local maize prices with respect to increases in global maize prices and global oil prices, based on the findings in previous tables. Entries are the products of elasticity estimates from the price transmission chain.

Local maize price elasticities with respect to global maize prices (column 1) are highest in Ethiopia (0.74–0.82) and lower but still substantial in the other three countries, ranging 0.20–0.24 in Kenya, 0.22–0.35 in Tanzania, and 0.23–0.53 in Uganda. Dampening of maize-to-maize price transmission primarily occurs across international frontiers (table 2); we have already seen that within each country, long-run spatial equilibrium in maize prices corresponds reasonably well to the LOP.

The key findings in table 6 are the cumulative impacts of global oil price changes on local maize prices (column 2). In the Kenya markets, as well as in the more remote markets of Gulu and Mbarara in Uganda, and Kigoma, Tanzania, the elasticity of local maize to global oil price is greater than or equal to the elasticity of local maize to global maize. In Mbeya, Tanzania, one of the other

Table 6. Cumulative Pass-Through Elasticities

Country	Market	Elasticity of local maize prices with respect to . . . Global Maize	Global Oil
ET	Addis Ababa	0.82	0.36
	Bahir Dar	0.81	0.35
	Dire Dawa	0.76	0.34
	Mek'ele	0.74	0.30
	ET average	0.79	0.34
KY	Kisumu	0.22	0.41
	Mombasa	0.22	0.31
	Nairobi	0.20	0.33
	Nakuru	0.24	0.35
	KY average	0.22	0.35
TZ	Arusha	0.33	0.10
	Dar es Salaam	0.35	0.08
	Dodoma	0.35	0.10
	Kigoma	0.22	0.24
	Mbeya	0.28	0.19
	TZ average	0.31	0.14
UG	Gulu	0.31	0.31
	Kampala	0.47	0.24
	Mbale	0.53	0.03
	Mbarara	0.23	0.40
	UG average	0.38	0.24
Overall average		0.42	0.26

Notes: Authors' calculations using first stage results in tables 1–4.

remote trading centers in the study (though still a major maize producing region), the estimated global oil price elasticity (0.19) is two thirds of the estimated global maize price elasticity (0.28). For markets in Ethiopia, as well as Kampala, Arusha, and Dar es Salaam (the largest cities in Uganda and Tanzania), cumulative global oil price elasticities are roughly a third to a half of the magnitude of global maize price elasticities. Across the sample, the average global maize price elasticity is 0.42, while the average global oil price elasticity is 0.26. Recall that these estimates assume no link between oil and maize prices on global markets. If such links exist, the average elasticity of local maize to global oil is greater than 0.26.

Putting these results together, what do we expect to happen when global commodity prices co-move, as they commonly do? If global oil and global maize prices simultaneously increase by 1%, long-run pass-through rates to local maize prices are about 100% in Ethiopia, 53%–63% in Kenya, 43%–47% in Tanzania, and 56%–71% in Uganda.

Lastly, we consider the importance of remoteness and the spatial variation in the estimated elasticities. In the furthest inland markets in our study (Gulu, Mbarara, Kigoma, and arguably Mbeya), transport costs are as or nearly as important as POE maize prices in determining maize prices. To highlight this point, figure 4 plots the difference between the elasticity of local maize with respect to global oil and the elasticity of local maize with respect to global maize against the distance in kilometers from the POE. The figure includes both country-specific trend lines and an overall trend (the solid line). With only 17 markets, this evidence is suggestive at best. But the clear pattern is that as one moves further from the port of entry, the relative importance of the oil price to local food prices increases.[14]

Conclusions

The potential for global oil price shocks to disrupt food markets in developing countries is of serious concern. We systematically examine the global oil–local food price link in east African maize markets. To our knowledge this is the first study to explore both inter- and intra-national price transmission from oil to cereals markets. We estimate price transmission from global crude oil markets to national and subnational petrol fuel markets in east Africa and then repeat the exercise for maize markets, allowing transport fuel prices to influence maize price spreads.

We find that both global oil and global maize prices exert considerable influence on

[14] Note that this finding is based on the average responsiveness of the local maize price to changes in the global oil and maize prices, not on static decompositions of marketing margins into their transport cost components, wholesale grain components, etc. Such decompositions are of limited use in understanding responsiveness to changes because unlike equilibrium price relationships estimated over time (which is what we report) they do not account for the underlying elasticities of substitution between food goods. In fact, the oil price elasticity may be greater than the maize price elasticity even if the transport fuel share in food costs is less than the wholesale cost of grain (or vice versa), because fuel price changes affect the cost of all traded goods, while pass-through of global maize prices is potentially mitigated by substitution between grains or consumption from stocks.

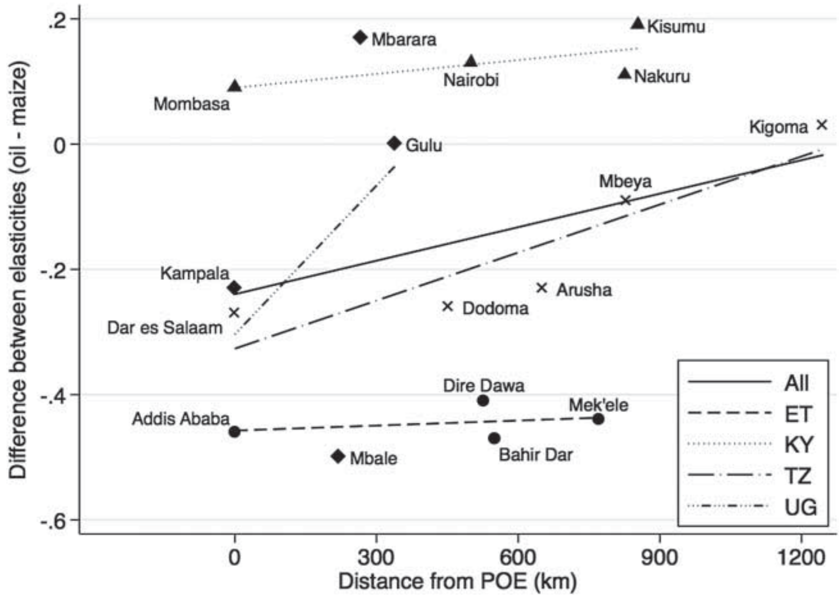

Figure 4. (Elasticity of local maize to global oil) – (Elasticity of local maize to global maize) plotted against distance from POE

maize prices. Cross-border price transmission is less complete than that within countries, with the latter largely following the LOP in long-run equilibrium for both maize and petrol. Yet our most conservative estimates still suggest an average pass-through price elasticity from global oil to local maize of 0.26. Estimates that allow for correlated oil and maize price changes approach or exceed unity.

Global oil price shocks transmit quickly to local maize prices, with adjustments to the new equilibrium typically taking place within a few months. The transmission from global maize to local maize is notably slower, likely owing to localized supply responses as well as endogenous policy interventions and infrastructural bottlenecks. Oil price impacts vary with overland travel distance. In the markets farthest from coastal ports, fuel price increases put greater upward pressure on local maize prices than do POE maize prices. The implication is that for remote regions, policymakers concerned about the impacts of food prices on poverty and food security should pay at least as much attention to global oil markets and their effects on transport costs as they do to the cereals markets.

These findings have other important policy implications. For price-taking economies, and especially for landlocked regions, policies to mitigate the negative consequences of grain price shocks by directly intervening in both transport and grain markets, rather than just the latter, are more likely to achieve food security objectives. Increased high-level attention to global food security tends to focus on farm productivity growth and on consumer safety nets. Although these are clearly high priorities, it is also essential to increase efficiency in post-harvest systems—including transport—that deliver food to rapidly urbanizing populations from both domestic farmers and global markets.

Supplementary Material

Supplementary online appendix is available at http://oxfordjournals.org/our_journals/ajae/online.

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