The Linkage between the U.S. Ethanol Market and World Hunger:

A Panel SVAR Analysis

Hao, N.[a], Pedroni, P.[b], Colson, G.[a], Wetzstein, M.[c]

[a] Department of Agricultural and Applied Economics, University of Georgia, Athens, Georgia, U.S.A.

[b] Department of Economics, Williams College, Williamstown, Massachusetts, U.S.A.

[c] Department of Agricultural Economics, Purdue University, West Lafayette, Indiana, U.S.A.

Address correspondence to:
Na Hao
326 Cannons Way
Newark, DE 19713
herby.hao@gmail.com

Abstract

The major expansion of U.S. ethanol production raises concerns about the potential detrimental impacts on developing countries' agricultural prices, farm income, and food security. For the purpose of understanding the sensitivity of maize prices to ethanol production, this study explores the linkage between the U.S. ethanol market and developing countries' maize prices. The econometric approach, based on a panel structural vector autoregression model, captures market interdependencies and the likelihood that developing countries' responses are both heterogeneous and dynamic. The results indicate that the U.S. ethanol market's impacts on maize prices in developing countries are heterogeneous and that coastal countries are more susceptible to U.S. economic shocks. The estimates also suggest that countries more dependent on food imports and/or receiving U.S. food aid are at a higher risk of being affected by such shocks. Overall, the results indicate that those countries with the greatest sensitivity and exposure to global agricultural commodity markets could benefit from domestic policies and international assistance, which reduce their exposure to impacts from the U.S. maize market.

Keywords: Ethanol, Food security, Maize, Panel Structural Vector Autoregression, World Hunger

JEL Classification: Q17 Q18 Q43

1. Introduction

U.S. ethanol production, encouraged by a range of government incentives, mandates, and subsidies, has caused debate concerning whether sustainable bioenergy from food is leading to greater food insecurity in developing countries (Avery, 2006; Cassman and Liska, 2007; Tenenbaum, 2008; Wise, 2012a). In the developing world, higher agricultural commodity prices due to increased ethanol production and inelastic commodity demand are of particular concern. Underlying this concern is the majority of developing countries are net food importers, with a high proportion of the world's food-deficit population (Valdes and Foster, 2012). This results in the world's poor being disproportionately affected by volatile agricultural commodity prices (Kornher and Kalkuhl, 2013).

For decades, international markets have represented a major destination for U.S. agricultural products (U.S. Grains, 2015). U.S. maize exports comprise one-third of world maize trade, with the United States exporting 48.78 million metric tons of the 131.10 million metric tons traded in 2013/2014 (WASDE, 2015). In contrast, maize net-import countries comprise most of the developing world. With increased U.S. maize-ethanol production potentially crowding out exports, it is possible U.S. ethanol production is a driver of increased global food price volatility.

However, not every country is experiencing the same maize price increase with U.S. ethanol expansion. In Nicaragua, the average annual real maize price declined from 0.31 USD per kilogram in 2006 to 0.21 USD per kilogram in 2012 (GIEWS, 2014). Some developing countries may experience greater commodity price volatility than others. For effective policies and programs designed to mitigate price volatility, research should be directed toward understanding such country-specific effects. Recent literature indicates little empirical support for the hypothesis that oil price shocks are transmitted to maize prices on global markets; rather, they seem to share common drivers (Dillon and Barrett, 2015; Zilberman et al., 2013; Zhang et al. 2010). However, Dillon and Barrett (2015) do indicate global petroleum prices can affect food prices through transport costs, but not through biofuel or production cost channels.

Although some previous research suggests volatile world maize prices result from U.S. ethanol production (Wise, 2012a, b; Actionaid, 2012). Empirical evidence on the relationships among food importation, U.S. trade effects, and geographically diverse countries is required before stating any definitive conclusions. To bridge this gap, this study tests the underlying hypothesis that U.S. ethanol demand and supply have differential impacts on developing countries' maize prices. Specifically, these impacts on developing countries' domestic maize prices may differ in response to U.S. ethanol demand and supply shocks.

Testing this hypothesis will provide an understanding of the mechanisms and consequences of U.S. ethanol market transmission effects on food prices in developing countries. In particular, the aim is to explore the hypothesis that transmission effects are systematically differentiated in countries with food importation, U.S. food aid, and specific geographic characteristics (coastal/isolated and African/Latin American countries).

Empirical research on food price transmission across countries is scarce, and the conclusion regarding which countries tend to be more vulnerable to the world market is far from established. The 2008 G8 summit emphasized that small island economies and landlocked countries with higher than average transportation costs (i.e., isolated countries) are especially vulnerable in the face of oil shocks (World Bank, 2008). However, recent studies have indicated that although landlocked countries are experiencing higher volatility, coastal countries can be even more affected by specific shocks, such as U.S. ethanol demand shocks (Dillon and Barrett, 2015; Kornher and Kalkuhl, 2013). Thus, coastal countries should be paid no less attention when facing global economic shocks. In addition, from a political perspective, African and Latin American countries belong to different organizational and political groups; thus, global organizations inevitably consider this so-called "continental effect" when formulating policy.

In order to explore this transmission effect, a recently developed panel structural vector autoregression (SVAR) approach is utilized and populated with U.S. ethanol demand and maize prices, as well as maize prices in developing countries. Conventional dynamic panel methods are unsuitable, as they require the dynamics of country-specific responses to be homogeneous among all countries, which is restrictive considering that developing countries likely respond to U.S. ethanol and maize markets in a dynamic and heterogeneous manner. Furthermore, market interdependencies exist, which imply countries are linked cross-sectionally with common global and regional shocks. To address these issues in the context of structural identification, a panel SVAR methodology developed by Pedroni (2013) is employed.

Empirically, with the exception of Kornher and Kalkuhl (2013), who adopt a generalized method of moments approach, research generally employs time series modeling. However, employing a standard time series analysis for estimating country-specific effects poses two empirical challenges (Pedroni, 2013; Mishra et al., 2014). First, for the many countries that exhibit a relatively short span of data available, a standard time series analysis would not be reliable. Second, data from many of these countries are noisy, so even when a span of data is available, a conventional time series analysis for any one country may not be reliable. These empirical challenges are addressed by expanding the panel dimension of the data to increase the reliability of the inferences (Pedroni, 2013; Mishra et al., 2014).

2. Empirical strategy

As previously discussed, two key features of the relationship between the U.S. ethanol market and maize prices in developing countries are the market interdependencies and the likelihood that responses are both dynamic and heterogeneous across developing countries. Such features should be accommodated in a viable panel analysis. In particular, ignoring cross-country heterogeneity in the dynamic responses in favor of treating them as if they were homogeneous leads to inconsistent estimation of the associated coefficients even if one is only interested in measuring the average response among countries. Furthermore, such an analysis precludes studying the pattern of heterogeneous responses as is our focus. Similarly, ignoring the interdependencies among countries induced by the linkages to the dynamics of a single large economy such as the United States risks drawing inconsistent inferences concerning their relationships. For these reasons, panel time series methods fundamentally treat the dynamics as potentially heterogeneous and interdependent among countries.

These features are accommodated by employing a panel time series approach as a special case of the panel SVAR methodology developed by Pedroni (2013). The methodology developed in Pedroni (2013) is sufficiently general for treating cases in which the source of common shocks affecting countries of the panel is unknown and must be inferred indirectly by employing cross-sectional averages of the country-specific time series. Under this methodology, the orthogonality conditions that arise from standard forms of structural identification in turn allow the decomposition of the unobserved structural shocks into common and idiosyncratic components in a manner that can be implemented successfully in relatively short panels. Recent applications of this methodology include Mishra et al. (2014).

As a special case, the primary interest of this paper is to study the consequences of common shocks that specifically originate in the U.S. market. Distinct from the Pedroni (2013) general methodology, the source of the common shocks is treated as known and originating in the United States. Furthermore, developing countries in the sample are treated as small open economies, which are impacted by these U.S. shocks, but are too small to affect the U.S. economy. These two assumptions taken together imply that rather than using cross-sectional averages of the panel of countries to infer the common shocks as in the general methodology, the U.S. data is employed to infer the common shocks. The structural identification of these U.S.-based shocks in turn allows examining the developing country-specific responses and thereby estimate the sample distribution of developing country responses.

Specifically, this set up can be represented as a special case of the methodology developed by Pedroni (2013) wherein the vector of series consists of a mix of panel time series data and pure time series data. This is shown by letting $z_{it} = (q_t, p_t, p_{it})'$ be a vector representation of the data, which has been demeaned to eliminate the fixed effects such that q_t is the demeaned log of the quantity of ethanol produced in the United States in a given month, p_t is the demeaned log of the maize price in the United States in a given month, and p_{it} is the demeaned log of the maize price in developing country i for a given month t. This represents a special case of the typical data structure used in Pedroni (2013) in that the first two entries in z_{it}, namely q_t and p_t, have reduced dimensionality such that they are standard time series variables from a single country rather than panel time series variables from a collection of countries. Furthermore, in contrast to the general methodology, on the basis of our specific small open economy assumptions, these two variables deliver the known source of the common shocks that affects developing countries' maize prices, p_{it}.

The consequences for p_{it} arising from movements in U.S. equilibrium quantities, q_t and p_t, are likely to depend both quantitatively and qualitatively on the reasons for the movements. For example, if the U.S. market is responding to an increase in United States or global demand (supply) for ethanol or maize, this is more likely yield upward (downward) pressure on developing countries' maize prices. If the distinctions between these two sources of U.S. market movements are ignored, confounding the two opposing effects can give the false impression of a relatively small quantitative effect of the U.S. market on developing countries. These two opposing effects are distinguished by structurally identifying the common shocks as originating on the supply or demand side.

For this purpose, a standard structural identification assumption is imposed, which considers the long-run ethanol supply to be inelastic to the U.S. maize price. U.S. federal ethanol supply mandates implicitly decouple ethanol supply from maize price affects, which yields the inelastic supply. Thus, while short-run supply is allowed to be elastic with respect to the maize price, the long-run supply is treated as inelastic. Under this simple assumption, ethanol demand shocks have a transitory effect on equilibrium ethanol quantities, but no long run effect. In the long run, only ethanol supply shocks have a permanent effect on equilibrium quantities. By contrast, ethanol supply and demand shocks can have both transitory and permanent effects on equilibrium prices. This setup allows U.S. ethanol supply and demand shocks to be identified and disentangled from one another on the basis of current market restrictions, namely that the long-run equilibrium quantity at the steady state is invariant to demand shocks.[1]

For fully identifying the effects of these shocks on developing countries' maize prices, shocks influencing a country's maize price originating in corresponding developing countries should be controlled. Disentangling these country specific shocks is accomplished with the small open economy assumption. Conceptually, it is assumed the shocks originating in these countries are individually too small to have a noticeable impact on the U.S. market. This implies a shock that moves a local country's maize price, but not the U.S. price or quantity, must be a country-specific shock originating in a small country. Technically, for our identification to be complete, we only require that this timing invariance occurs at the long-run steady state. However, to take full advantage of the small open economy assumption, the restriction is imposed over all time horizons. With these country-specific shocks serving as controls rather than objects of interest, further disentangling the specific nature of these shocks is unnecessary, and accordingly all such shocks are grouped into one category for each country.

The full set of restrictions described informally above can also be presented formally, both mathematically and graphically. For the former, the set of structural responses of the variables to the shocks are represented in vector moving average form, from which the impulse responses and variance decompositions are obtained. Specifically, given each of the variables in $z_{it} = (q_t, p_t, p_{it})'$ are confirmed to be well approximated by unit root processes, they can be represented as stationary vector moving average in log differences $\Delta z_{it} = A_i(L)\epsilon_{it}$, where $\Delta z_{it} = (\Delta q_t, \Delta p_t, \Delta p_{it})'$ are the demeaned growth rates of the data and $\epsilon_{it} = (\epsilon_t^S, \epsilon_t^D, \epsilon_t^C)'$ are the structurally identified shocks corresponding to supply shocks to the U.S. ethanol market, ϵ_t^S, demand shocks to the U.S. ethanol market, ϵ_t^D, and

[1] Consistent with this identification scheme, the ADF test with trend and intercept fails to reject the unit root null hypothesis for U.S. ethanol price and quantity series, with statistical values of -2.22 and -2.04 respectively.

country-specific shocks, ϵ_{it}^{C}. The 3×3 polynomial matrix, $A_i(L) = \sum_{s=0}^{Q_t} A_{i,s} L^s$ represents the structurally identified responses of the observed variables, Δz_{it} to the unobserved structural shocks ϵ_{it}, from which the structural impulse responses and variance decompositions are obtained. The identifying restrictions are imposed in terms of the steady-state restrictions on A_i, which can be represented succinctly as $A(1)_{1,2} = A_i(1)_{1,3} = A_i\,(1)_{2,3} = 0$, where $A_i(1) = \lim_{Q_i \to \infty} \sum_{s=0}^{Q_i} A_{i,s}$ represents the steady-state responses of the log levels z_{it} to the structural shocks ϵ_{it}.

In particular, $A(1)_{1,2} = 0$ indicates that U.S. demand shocks ε_t^D have no long-run steady-state effect on the equilibrium U.S. log quantity of ethanol, q_t. Similarly $A_i(1)_{1,3} = A_i(1)_{2,3} = 0$ indicate that country-specific shocks ϵ_{it}^{C} have no long-run steady state effect on either the U.S equilibrium log quantities, q_t, or log prices, p_t. The combination of these restrictions is sufficient to uniquely identify the country specific structural responses to each of the structural shocks. Furthermore, we exploit additional over-identifying restrictions from the small open economy assumption such that $A_{i,s,1,3} = A_{i,s,2,3} = 0$ for all time horizons, s, which is equivalent to assuming that individual small open economies do not Granger cause variables in the United States. All other dynamic responses are left unrestricted. The specific method of estimation is through the transformation of the reduced-form VAR estimates subject to these identifying restrictions; refer to Pedroni (2013) for further estimation details.

An equivalent way in which to visualize these identifying restrictions is to represent the estimated structural impulse responses and variance decompositions graphically. In particular, Figures 1 and 2 present the estimated structural impulse responses and variance decompositions for our identification scheme. Both figures arrange the graphics as a 3 × 3 matrix, corresponding to the dimensions of the $A_i(L)$ polynomial response matrix. Accordingly, the four graphics in the upper left-hand quadrant, corresponding to $A(L)_{1,1}$, $A(L)_{1,2}$, $A(L)_{2,1}$, and $A(L)_{2,2}$represent the response of the U.S. market to U.S.

supply and demand shocks and are used to identify the common shocks of interest. In particular, the steady-state restriction that disentangles supply versus demand shocks can be observed by noting $A(L)_{1,2}$, the response of demeaned log equilibrium ethanol quantities, eventually returns back to the origin following an initial expansion. The transition dynamics that move the economy back to the steady state are left unrestricted, as are both the transition dynamics and the steady-state dynamics in the other three graphics of the upper left-hand quadrant.

By contrast, as observed in both figures, the $A_i(L)_{1,3}$ and $A_i(L)_{2,3}$ graphics are flat at zero for all countries, i, as these represent the small open economy assumption that shocks originating in developing countries individually have no impact on the U.S. equilibrium variables. These restrictions serve to disentangle the local country shocks from the common shocks originating in the Unites States. The responses of each country's maize prices to the local country shocks are then depicted in the $A_i(L)_{3,3}$ graphic in the lower right-hand corner of both figures. As observe in the figures, the dynamic responses are heterogeneous and differ among countries. Correspondingly, the median as well as the 25% and 75% country quantile responses are depicted, meaning for example that the estimated responses of at least 75% of the sample countries fall below the 75% quantile.

The estimates of primary interest are depicted in the $A_i(L)_{3,1}$ and $A_i(L)_{3,2}$ responses in the two left-hand graphics in the bottom rows of Figures 1 and 2. These responses are entirely unrestricted in the estimation. Again, the estimated dynamic responses are heterogeneous among countries and, accordingly, the figures depict the median response among countries as well as the 25% and 75% quantiles.

Figure 2 is arranged in an entirely analogous framework as Figure 1, but reports the dynamic variance decompositions rather than impulse responses. These dynamic variance decompositions represent estimates of the relative contribution of the various structural shocks to the variation in the observed variables at different time horizons following the shock. Correspondingly, these are also heterogeneous among countries, with the median, 25%, and 75% quantiles of the sample distribution depicted in the figures. These are simply the quantiles summarized graphically, while the estimation method produces the entire sample distribution of the structural impulse responses and variance decompositions for each developing country. Appendix Table A1 lists the 38 developing countries considered and Table A.2 ranks the countries in terms of their order of susceptibility to U.S. demand and supply ethanol shocks. The patterns in these estimated responses are informative in that they may reveal which developing country characteristics are associated with particularly small or large responses to shocks originating in the U.S. ethanol market.

3. Data

The choice of the country panel is guided by the desire to limit attention to developing countries with available and reliable monthly data on maize prices. This yields monthly real price series of maize adjusted by local inflation rates for 38 countries from January 2006 to January 2015, Appendix Table A.1 (GIEWS, 2014). U.S. monthly maize prices are taken from USDA and ethanol production is from the Energy Information Administration (EIA, 2015; USDA, 2015). Both price series are adjusted by the CPI with 2005 as the base year.

Table 1 presents the summary statistics for the monthly adjusted maize price series. Compared with developing countries, the mean of U.S. maize prices is relatively low and associated with a lower coefficient of variation. This indicates greater stability in the U.S. food market relative to other markets. Skewness indicates that maize prices in both the United States and the developing countries exhibit longer right tail distributions, with the latter exhibiting a larger effect. The kurtosis for prices in the developing countries is markedly higher than that for U.S. prices, which indicates that more of the variance is the result of infrequent extreme deviation as opposed to U.S. maize prices (platykurtic distribution).

4. Results

The impulse responses and variance decompositions depicted in Figures 1 and 2 are now evaluated in terms of a developing country's dependence on U.S. food aid, food imports, and coastal/continental effects. U.S. food aid dependency is indicated by the average annual ratio of U.S. maize donations to the domestic supply from 2006 to 2012 (World Food Program, 2015; FAOSTAT, 2015). In this period, 20 countries out of 38 received zero U.S. aid. Food import dependency is indicated by the average cereal imports dependency ratio from 2006 to 2011 (FAO, 2015). All countries import maize. The coastal dummy variable, measuring geographic effects, equals 1 for a country that shares a border with another country and has a coastline, and 0 for an isolated country. Thus, Cabo Verde, an island country, is defined as isolated rather than coastal (Appendix Table A.1.)

As indicated in Figure 1, the impact of a U.S. ethanol supply shock on developing countries' maize prices is markedly lower than from an ethanol demand shock. A U.S. ethanol demand shock increases maize prices in approximately 75% of the developing countries. This increase is also persistent. In contrast, an ethanol supply shock has mixed results. Slightly fewer than 50% of the countries experience no increase or even a decline in their prices. Developing countries' price flexibility to U.S. ethanol supply is less responsive than to U.S. ethanol demand. This finding indicates an ethanol demand shock, possibly from an increase in U.S. federal mandates, tends to have a positive impact on developing countries' maize prices. In contrast, an ethanol supply shock has mixed results on developing country prices. In terms of the variance decompositions, the contributions of ethanol supply and demand shocks appear to be similar on average, although there is considerable spread in the relative contributions among countries.

In order to explore the determinants of this variation in impulse responses and variance decompositions, the cross-sectional associations among certain country characteristics are examined. In particular, three factors are considered, which may influence the strength of transmissions: geographic effects, food import dependency, and U.S. food aid dependency. The impulse responses and variance decomposition in the first month across the 38 developing countries are thus regressed on these three factors (Table 2).

As concluded by Cachia (2014), the maximum impact of a shock in developing regions is generally felt within the initial months, with the domestic adjustment varying by country. In this vein, the first three-post shock months are considered. With the results similar across the months, only the first month is reported in Table 2. In this first month, an F test for the regression of the response of maize prices in developing countries to a U.S. ethanol supply shock is significant at the 1% level with a relatively high R^2 of 0.42. This regression along with the companion regression for variance decomposition indicates developing countries' maize price response to a U.S. ethanol supply shock is positively related to their U.S. food aid dependency at the 1% and 10% significance levels for the impulse responses and variance decompositions, respectively (Table 2). A positive response is also associated with food import dependency in the variance decomposition supply shock. This finding directly supports the hypothesis that countries with higher food import dependency are more susceptible to the U.S. ethanol market. The associated elasticities calculated at the means are inelastic (0.674 and 0.128 for U.S. food aid impulse response and decompositions, respectively, and 0.778 for food import dependency variance decomposition). This suggests the response of the maize price in a developing country to a U.S. supply shock is not very responsive to U.S. food aid dependency. Hence, food import-dependent countries have a similar ability to adjust to U.S. ethanol supply shocks relative to other countries. The global maize market thus appears to distribute any U.S. supply shock evenly across countries.

The maize price response of developing countries to a U.S. ethanol demand shock is significantly weaker than that of an ethanol supply shock. The F statistics are only significant at the 10% level and the adjusted R^2 values are lower. In terms of U.S. food aid dependency, there is no significant relation at the 10% level or above. Further food import dependency is significant in the demand shock regressions, but the signs are negative. These negative influences may indicate some tâtonnement in reestablishing the equilibrium from a U.S. market shock. Food dependency does lead to greater price volatility. In contrast to the supply shock, the demand shocks are elastic (-1.307 and -1.116, for impulse response and variance decomposition, respectively). The results again indicate a weak, if any, relation of food dependency with a country's maize price from a U.S. maize market shock. This result supports the conclusion by Cachia (2014), which states the relative size of a domestic response depends on the share of imports in domestic demand (import dependency ratio). Note that the World Bank cereal import dependency ratio was also considered with similar results in terms of signs and significance, which indicates the robustness of the results.

Regarding the continental and coastal effects, African countries are not significantly affected at the 10% level by a U.S. maize market shock relative to other countries. In contrast, coastal countries are more susceptible than isolated countries to a U.S. ethanol demand shock. The magnitude of these effects is markedly larger than the food dependency effects. This finding is consistent with those of previous studies, which suggest that landlocked countries cannot rely as much on food imports and thus are less exposed to international price shocks (Kornher and Kalkuhl, 2013). However, the effect does not appear to affect the response to U.S. ethanol supply shocks.

5. Conclusions and policy implications

Employing a panel time series method across developing countries exploits their potential heterogeneous and interdependent nature. The resulting empirical estimates thus offer insights into the linkages between maize prices in developing countries and U.S. ethanol and maize markets. The hypothesis that

U.S. ethanol demand and supply have differential impacts on developing countries' maize prices is supported by the results. Specifically, the results illustrate the importance of employing a methodology that addresses the market interdependence and developing countries' heterogeneous response to market shocks as well as addressing the distinction between global demand and global supply shocks. These different developing country responses can then be employed to reveal country characteristics, which are associated with particularly small or large responses. The results also indicate that food dependency and coastal geography can explain the price response of developing countries. However, coastal geography does help to significantly explain the price response pattern for a U.S. ethanol demand shock.

The impacts for food dependent countries as well as geographic coastal effects indicate that the market interdependencies are far more complex than previous modeling efforts have considered. This suggests that a single overarching policy may not efficiently address hunger issues. Consistent with the existing body of research, the results further indicate that although landlocked countries are experiencing higher volatility, when holding other factors constant, coastal countries are even more susceptible to a world economic shock. Thus, coastal countries should be paid no less attention when facing global economic shocks such as those originating from U.S. ethanol markets.

These results run counter to the ideals of free trade. Greater exposure to global agricultural commodity markets yields heightened susceptibility to price shocks from abroad. In terms of U.S. ethanol demand and supply shocks, countries more dependent on food imports (including Colombia, Congo, Guatemala, Honduras, and Niger) and/or receiving U.S. food aid (Congo, Niger, Honduras, and Kenya) are at only a slightly higher risk of their domestic maize prices being affected. In contrast, a country receiving limited food imports and U.S. food aid, is at only a slightly lower risk of global agricultural commodity market shocks affecting their domestic prices (e.g., Ukraine, Haiti, and Mozambique). A country with greater exposure to global agricultural markets may want to consider mitigating this susceptibility. One option in this regard would be to diversify the agricultural sector with more country-specific traditional commodities. With such diversification comes reduced price risk through the portfolio effect. With the recent higher volatility in agricultural commodity prices, policies encouraging an emphasis on locally grown can take on greater significance.

The trade rules negotiated by the World Trade Organization could offer hope on key issues affecting the most vulnerable. Limits on subsidies in developed countries, expanded market access for developing country goods, and protection for the poorest farmers are generally overarching. Such policies may provide a foundation for addressing global market shocks such as biofuel policies in developed countries. However, the results presented indicate that specific policies addressing the differing characteristics of developing countries are required to mitigate negative global market shocks. Until recently, multilateral talks focused almost exclusively on issues that were the product of an era of historically stable and declining food prices. Trade talks need to reflect the changing realities, such as countries limiting exports, biofuel policies tying food to fuel, and the increasingly risky nature of agriculture. Governments should address these challenges collectively. Unpredictable climatic conditions and volatile prices may require more targeted policies to ensure that enough food is accessible and available for all.

The United States and other countries along with international institutions that aim to reduce poverty and malnourishment in developing countries must guard against the possible consequences of U.S. ethanol production and target the most vulnerable countries. Policies such as food aid and agricultural commodity buffers designed to blunt these price spikes could be developed and implemented accordingly. However, care is required in implementing these policies. Moreover, the determination of a typology of countries with respect to their exposure to shocks would contribute toward improving the design of food security policies. This understanding of the empirical linkages between U.S. ethanol and maize markets and international maize prices could be expected to improve forecasts that feed into early warning systems for food security (Cachia, 2014).

References

Avery, Dennis (2006). *Biofuels, Food, or Wildlife? The Massive Land Costs of U.S. Ethanol.* Competitive Enterprise Institute Advancing Liberty from the Economy to Ecology. Issue Analysis, Number 5, 2006.

ActionAid (2012). *Fueling The Food Crisis: The Cost to Developing Countries of US Corn Ethanol Expansion.* http://www.ase.tufts.edu/gdae/Pubs/rp/ActionAid_Fueling_Food_Crisis.pdf

Cachia, Franck (2014). *Regional Food Price Inflation Transmission.* FAO Statistics Division Working Paper ESS/14-01 http://www.fao.org/docrep/019/i3718e/i3718e.pdf

Cassman, Kenneth G. and Adam J. Liska (2007). "Food and Fuel for All: Realistic or Foolish?" Biofuels, Bioproducts and Biorefining. Volume 1, issue 1 (2007):18-23.

Dillon, Brian M. and Christopher B. Barrett (2015). "Global Oil Prices and Local Food Prices: Evidence from East Africa," American Journal of Agricultural Economics, doi: 10.1093/ajae/aav040.

EIA (2015). *Monthly Fuel Ethanol Production Demand.* http://ethanolrfa.org/pages/monthly-fuel-ethanol-production-demand

FAO (2015). *Cereal Import Dependency Ratio.* http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/#.VT-bHvnF8eo

FAOSTAT (2015). *Food Balance Sheets.* http://faostat.fao.org/site/368/DesktopDefault.aspx?PageID=368#ancor

Global information and early warning system (GIEWS), FAO (2015). http://www.fao.org/giews/english/index.htm

Kornher, Lukas and Matthias Kalkuhl (2013). *Food Price Volatility In Developing Countries And Its Determinants*. No 156132, 53rd Annual Conference, Berlin, Germany, September 25-27, 2013 from German Association of Agricultural Economists.

Mishra, Prachi, Peter Montiel, Peter Pedroni, and Antonio Spilimbergo (2014). "Monetary policy and bank lending rates in low-income countries: Heterogeneous panel estimates," Journal of Development Economics, Volume 111, 2014, 117–131.

Pedroni, Peter (2013). "Structural Panel VARs," Econometrics 2013, 1(2), 180-206.

Tenenbaum, David J. (2008). "Food vs. Fuel: Diversion of Crops Could Cause More Hunger," Environmental Health Perspectives. Volume 116, number 6, June 2008.

USDA (2015). *U.S. Monthly Maize Prices.* http://www.ers.usda.gov/data-products/agricultural-baseline-database.aspx

Valdes, Alberto, and William Foster (2012). *Net Food-Importing Developing Countries: Who They Are, And Policy Options for Global Price Volatility*. ICTSD Programme on Agricultural Trade and Sustainable Development, Issue Paper No. 43.
http://www.ictsd.org/downloads/2012/08/net-food-importing-developing-countries-who-they-are-and-policy-options-for-global-price-volatility.pdf

Wise, Timothy. A. (2012a). *The Cost to Mexico of U.S. Corn Ethanol Expansion*. Global Development and Environment Institute, Working Paper No. 12-01.

Wise, Timothy. A. (2012b). *The Cost to Developing Countries of U.S. Corn Ethanol Expansion*. Global Development and Environment Institute, Working Paper No. 12-02.

U.S. Grains (2015). *Corn-Production and Exports.* U.S. Grains Council.
http://www.grains.org/buyingselling/corn

World Agricultural Supply and Demand Estimates, USDA (2015). *World Corn Supply and Use 547-22*, November 10, 2015. http://usda.mannlib.cornell.edu/usda/current/wasde/wasde-11-10-2015.pdf

World Bank (2008). *Double Jeopardy: Responding to High Food and Fuel Prices.* G8 Hokkaido-Toyako Summit, July 2008.
http://siteresources.worldbank.org/INTPOVERTY/Resources/335642-1210859591030/G8-HL-summit-paper.pdf

World Food Program (2015). *Food Aid Information System.* http://www.wfp.org/fais/reports/quantities-delivered-report

Zhang, Zibin, Luanne Lohr, Cesar Escalante and Michael Wetzstein (2010). "Food versus fuel: What do prices tell us?," Energy Policy 38(1): 445-451.

Zilberman, David, Gal Hochman, Deepak Rajagopal, Steve Sexton and Govinda Timilsina (2013). "The Impact of Biofuels on Commodity Food Prices: Assessment of Findings," American Journal of Agricultural Economics 95 (2): 275–81.

Appendix

Table A.1. Country list

Country	Geography
Angola	Coastal
Argentina	Coastal
Benin	Coastal
Bolivia	Isolated
Brazil	Coastal
Burundi	Isolated
Cabo Verde	Isolated
Cameroon	Coastal
Central African Republic	Isolated
Chad	Isolated
Chile	Coastal
Colombia	Coastal
Congo, Rep.	Isolated
Dominican Republic	Coastal
Ethiopia	Isolated
Ghana	Coastal
Guatemala	Coastal
Haiti	Coastal
Honduras	Coastal
Kenya	Coastal
Malawi	Isolated
Mexico	Coastal
Morocco	Coastal
Mozambique	Coastal
Namibia	Coastal
Nicaragua	Isolated
Niger	Coastal
Panama	Isolated
Paraguay	Isolated
Peru	Coastal
Philippines	Isolated
Rwanda	Isolated
South Africa	Coastal
Tanzania	Coastal
Thailand	Coastal
Togo	Coastal
Ukraine	Coastal
Zambia	Isolated

Table A.2. Country order of susceptibility (high to low)

First Month			
Impulse Responses		Variance Decompositions	
Supply $A_iL_{3,1}$	Demand $A_iL_{3,2}$	Supply $A_iL_{3,1}$	Demand $A_iL_{3,2}$
Democratic Republic of the Congo	Togo	Democratic Republic of the Congo	South Africa
Togo	Benin	Nicaragua	Brazil
Kenya	Brazil	Haiti	Thailand
Bolivia	South Africa	Kenya	Argentina
Central African Republic	Argentina	Colombia	Chile
Haiti	Chad	Cabo Verde	Benin
Cabo Verde	Thailand	Namibia	Togo
Mozambique	Ukraine	Chile	Ukraine
Rwanda	Honduras	Bolivia	Philippines
Colombia	Chile	Republic of Moldova	Honduras
Paraguay	Philippines	Togo	Haiti
Chile	Kenya	Zambia	Chad
Panama	Central African Republic	Peru	Namibia
Benin	Paraguay	South Africa	Kenya
United Republic of Tanzania	Guatemala	Central African Republic	Guatemala
Ukraine	Namibia	Panama	Colombia
Peru	Bolivia	Ghana	Niger
Ethiopia	Colombia	Guatemala	Angola
Chad	Niger	Paraguay	Paraguay
Niger	Zambia	Rwanda	Panama
Thailand	Nicaragua	Mexico	Malawi
Angola	Dominican Republic	Cameroon	Burundi
Argentina	Rwanda	Dominican Republic	Central African Republic
Honduras	Cabo Verde	Mozambique	Zambia
Brazil	Ethiopia	Philippines	Republic of Moldova
Mexico	Mexico	Burundi	Bolivia
Malawi	Cameroon	Niger	Cabo Verde
Philippines	Democratic Republic of the Congo	Benin	Mexico
Burundi	Peru	Brazil	Nicaragua
Guatemala	United Republic of Tanzania	Ukraine	Peru
Cameroon	Ghana	United Republic of Tanzania	Dominican Republic
Dominican Republic	Angola	Ethiopia	Rwanda

South Africa	Mozambique	Malawi	Ethiopia
Zambia	Panama	Angola	Ghana
Namibia	Republic of Moldova	Chad	Mozambique
Ghana	Burundi	Argentina	United Republic of Tanzania
Republic of Moldova	Haiti	Honduras	Cameroon
Nicaragua	Malawi	Thailand	Democratic Republic of the Congo

Table 1. Summary statistics for monthly maize real price series, January 2006 to January 2015

Maize price($/kg)	United States	Total Developing Countries
Mean	0.16	0.36
Minimum	0.08	0.04
Maximum	0.26	9.03
Standard Deviation	0.05	0.56
Coefficient of Variation	0.31	1.54
Skewness	0.27	9.56
Kurtosis	2.03	120.72
Number of Countries	−	38

Table 2. Regression results[a]

	First Month			
	Impulse Responses		Variance Decompositions	
	Supply $A_iL_{3,1}$	Demand $A_iL_{3,2}$	Supply $A_iL_{3,1}$	Demand $A_iL_{3,2}$
Food Import Dependency	0.0002	−0.0004**	0.0005*	−0.0014*
	(0.0001)	(0.0001)	(0.0002)	(0.0005)
U.S. Food Aid Dependency	0.0003*	0.0001	0.0003***	0.0005
	(0.0001)	(0.0001)	(0.0002)	(0.0004)
African	0.0047	−0.0006	−0.0050	−0.0148
	(0.0052)	(0.0056)	(0.008)	(0.0200)
Coastal	−0.0054	0.0175***	−0.0090	0.0822*
	(0.0068)	(0.0073)	(0.0110)	(0.0261)
$F(4, 31)$	5.68*	2.39***	5.14*	3.56**
R^2	0.4229	0.2355	0.3986	0.3149
Adjusted R^2	0.3484	0.1368	0.3210	0.2265

[a] Standard errors are in the parentheses with *, **, and *** denoting 1%, 5%, and 10% level of significance, respectively. Food import dependency is the average of yearly ratio of cereal import dependency ratio from FAO (FAO, 2015). U.S. food aid dependency is U.S. maize aid over domestic supply. Africa is a dummy variable with 1 equaling an Africa country and 0 otherwise, and Coast is a dummy variable with 1 equaling a coastal country and 0 otherwise. Missing data resulted in Cabo Verde and Burundi being excluded from the analysis.

Figure 1

Impulse Responses

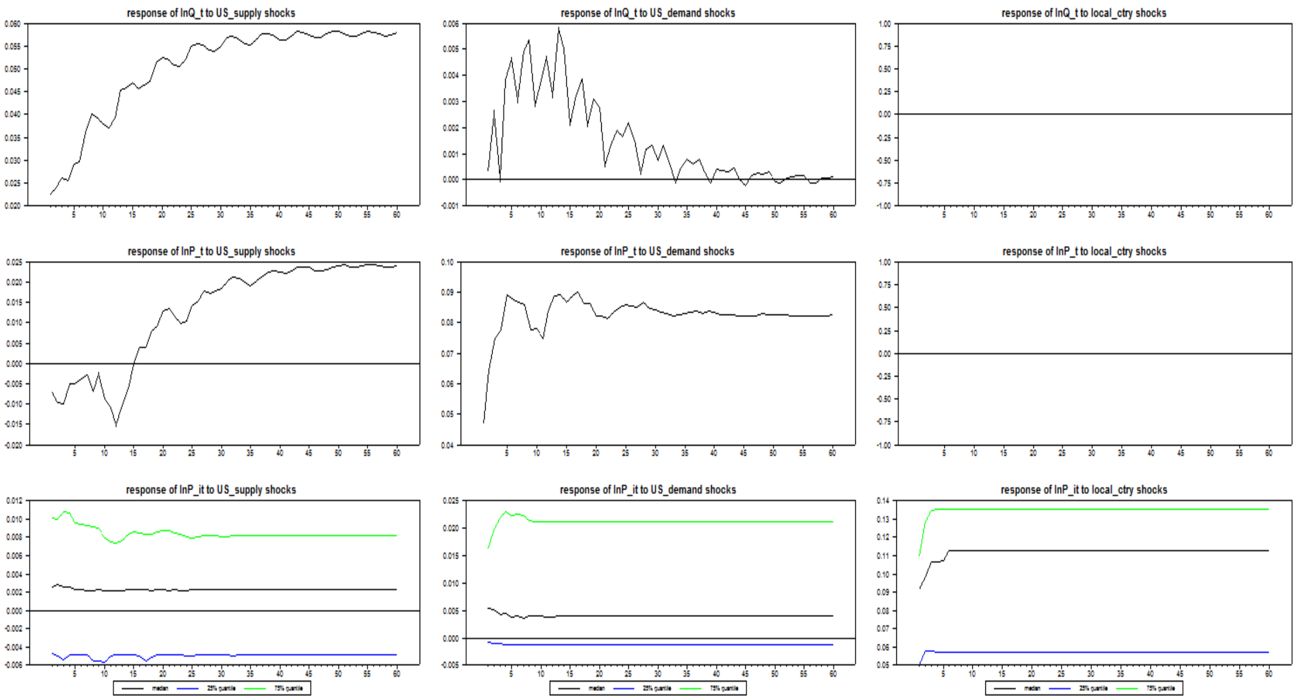

Figure 2

Variance Decompositions