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U.S. Ethanol Demand and World Hunger: Is There Any Connection?

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Selected Paper prepared for presentation at the 2015 Agricultural & Applied Economics Association and Western Agricultural Economics Association Annual Meeting, San Francisco, CA, July 26-28.

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Abstract

U.S. ethanol expansion objectives are to improve both energy security and the environmental. However, this expansion has raised issues concerning its detrimental impacts on the price volatility of developing countries' agricultural commodities. These concerns are addressed by empirically investigating the relations among U.S. ethanol and corn markets with developing countries' corn prices. Results indicate that U.S. ethanol demand impacts on developing countries' corn prices vary by country. Further, results reveal that the transmission effects of U.S. ethanol shocks are systematically stronger for countries with higher food import dependency and U.S. food aid.

Keywords: Ethanol, Food security, Panel structural vector autoregression, World hunger, Food aid

1. Introduction

U.S. ethanol production, encouraged by a range of government subsidies and incentives, has caused a debate whether sustainable bioenergy from food is causing greater food insecurity in developing countries (Wise, 2012a). Higher agricultural commodity prices due to increased ethanol production are of particular concern in developing countries. First, the majority of developing countries are net importers of food, which means that they often face world prices for agricultural commodities (Valdes 2012). Second, the world's poor are disproportionately affected by higher commodity prices due to inelastic demand for agricultural staples (Lucas, 2013).

Expanding U.S. production and consumption of corn-based ethanol is a major biofuel program, which is possibly causing food price inflation. For decades, international markets are a major destination for U.S. agriculture products (Dilivan, 2015). United States exports corn to most of the developing countries, including countries in Southeast Asia, South America, and Africa. Thus, any price volatility, possibly caused from bioenergy, can extend harm globally, particularly in developing countries.

U.S. corn exports comprise one-third of world corn trade, with U.S. exporting 48.7 million metric tons of the total 130.64 million metric tons traded in 2013/2014 (WASDE, 2015). In contrast, corn net-import countries comprise most of the developing world. With increased U.S. corn-ethanol production potentially crowding out exports, it is possible U.S. ethanol production is a major cause of increased global food prices.

Food price volatility harms the well-being of consumers, particularly those in developing countries, whose food expenditure can account for half or more of household income. In 2009, FAO estimated that the 2007-2008 price spike drove the number of undernourished people in the world from 915 million to more than 1 billion, the highest in over 40 years (FAO, 2009). A similar number of people are believed to be pushed into poverty and undernourishment as a result for the recent 2011-2012 price spike. Rising

food prices also may have triggered food riots and political unrest (Lagi et al., 2011; Roberts and Tran, 2013a).

However, on a closer examination, not every country is experiencing the same corn price increase with U.S. ethanol expansion. In Bolivia, average yearly real corn price in 2006 was 0.89 boliviano per kilogram, and it decreased to 0.87 boliviano per kilogram in 2012 (GIEWS, 2014). Some countries may benefit while some not. Thus, research should be directed toward determining the individual country effects.

Previous research suggests volatile import corn prices result from U.S. ethanol production (Wise, 2012a, b; Actionaid, 2012). However, this may not necessarily be the case for every country. Thus, empirical evidence deriving inferences on food importing, U.S. trade effects, and geographically diverse countries is required before any definitive conclusions can be reached. As a first attempt, the objective is to test the underlying hypothesis that U.S. ethanol demand has differential and possibly limited impact on developing countries' corn prices. A review of the literature indicates there is a gap in empirical research addressing this hypothesis. The aim is to fill this literature gap.

Testing this hypothesis will provide an understanding of the mechanisms and consequences of U.S. ethanol demand transmission effect on food prices in developing countries. In particular, the aim is to explore the hypothesis that transmission effects are systematically weaker in countries with specific geographic characteristics (coastal/isolated and African/American countries). For exploring this transmission effect, a recently developed panel SVAR model is utilized and populated with U.S. ethanol demand and corn prices, and corn prices in developing countries. Conventional dynamic panel methods are not appropriate, given they require the dynamics of individual country responses to be identical among all countries. Furthermore, it is important to consider countries are linked cross-sectionally with common global and regional shocks. For addressing these issues in the context of structural identification, a panel SVAR methodology developed in Pedroni (2013) is employed.

The aim is to then focus on developing countries' food import and U.S. trade dependency along with geographic effects (continental effect and coastal effect). Food import dependency is indicated as a long run average of imported over domestic cereal supply. Import dependency generally emerged among the world's poorest regions. Within developing countries, there are approximately 20 low-income food deficit countries with import/consumption ratios surpassing 50% (Hoering, 2013). Food import dependency is also an important indicator of food insecurity (FAO, 2015). With United States the world's major provider of international food aid to low-income developing countries, its aid is another potential covariate. U.S. food aid dependency is indicated as a long-run average ratio of U.S. corn donor over the domestic cereal supply. Substantial discussion exists on food aid with its potential domestic production disincentives and dependency effects (Garg, et al., 2013). The geographic character of a country is fixed, but can effect a country's susceptibility to U.S. corn exports. If a country is vulnerable due to inherent reasons, international aid may be particularly required.

At the 2008 G8 summit, it was emphasized that when facing oil shocks, especially vulnerable are small island economies and landlocked countries with higher than average transportation costs (World Bank, 2008). However, recent literature indicates that although landlocked countries are experiencing higher volatility coastal countries are even more affected by a specific shock, such as U.S. ethanol demand (Lukas and Matthias, 2013). Thus, the coastal countries should be paid no less attention when facing the world economic shocks. In addition to coastal and isolated countries, focus is also on the difference in African and developing American countries. From a political perspective, African and American countries belong to different organizational and political groups; the world organizations inevitably consider the continental effect when making any policy.

2. Literature

2.1. U.S. ethanol production

The potential severe implications of rising global food prices have sparked an extensive literature investigating the role played by the U.S. ethanol mandate (Roberts and Tran, 2013a). Studies of U.S. biofuels expansion generally focus on price impacts from biofuels policies (Wise, 2012a). The existing literature generally employs projected simulations and partial equilibrium modeling yielding different results. Studies on the impacts of biofuels on food and fuel have assumed that energy prices are either fixed or determined in competition (deGorter and Just, 2009; Rajagopal et al. 2009). Abbott et al. (2008) determined biofuel policies were responsible for approximately one-quarter global corn price inflation, the remainder attributable mainly to higher oil prices. Their follow-up study in 2011 suggested that two major drivers of global food prices in the 2010-11 price spike were U.S. biofuels and rising Chinese soybean demand (Abbott et al., 2011). Roberts and Schlenker (2013) calculated that the U.S. biofuel mandate caused a 30% increase in 2008 agricultural commodity prices.

The Organization for Economic Cooperation and Development (OECD) concluded if biofuel production remained at 2007 levels, rather than doubling over the next decade as projected, prices for coarse grains (primarily corn) would be 12% lower in 2017 (OECD, 2008). Hochman et al. (2010), employing a partial equilibrium model, determined if world corn ethanol were not produced, the price of corn would have been 7.26% lower in 2005 and 12.18% lower in 2007. Baier et al. (2009) concluded that worldwide biofuel production had pushed up corn prices by 27% from 2006 to 2008 and that U.S. biofuels production increased corn prices by more than 22%. In terms of global food prices, they found that just over 12% of the rise in the IMF's food price index could be attributed to biofuels, but that 60% of that contribution came from U.S. biofuels production. Lagi et al. (2012) calculated that from 2003-2004 to 2010-2011, U.S. ethanol expansion cost Mexico about \$3.2 billion, while financial speculation added another \$1.4 billion to the country's seven-year corn import bill.

In contrast, Hausman et al. (2012), Roberts and Schlenker (2013), Roberts and Tran, (2013b) and Rosegrant (2008), suggest that while ethanol mandate impacts were considerable, other factors, such as

bad weather and above-trend growth in food commodity demand, likely account for most of the world price increase and volatility changes since 2005. Al-Riffai et al. (2010) employs a global computable general equilibrium model (CGE) to estimate the impact of EU biofuels policies. Results indicate EU biofuels effect on food prices will remain very limited. Roberts and Tran (2013b) consider economic impacts of the U.S. ethanol mandate by modeling storage decisions. Excess demand from the U.S. ethanol mandate can be partly fulfilled by existing grain inventories. As a result, U.S. ethanol mandate impacts on food prices are small when grain storage is high. Laborde and Valin (2012) employed a CGE and evaluated indirect land-use changes due to EU biofuels and pointed out parameter uncertainties prevented a precise estimation on land-use change and associated emissions.

Babcock (2011) conclude the impacts of U.S. biofuel subsidies on crop prices were quite modest, which implies that ethanol subsidies were not the major driver of higher commodity prices including corn. Using Babcock's (2011) simulated results, Wise (2012b) further calculated net corn importing countries' loss due to U.S. ethanol expansion. Altogether, the ethanol-related losses totaled \$11.6 billion for all net corn importing countries. And developing countries incurred more than half the costs. Growmark (2013) concluded a larger effect on corn markets, than U.S. ethanol production, is investment flows channeled into the corn market by investors/speculators (speculation trumps ethanol demand).

Overall, the conclusions are far from definitive. Considering the methodology, the above analyses are generally based on large macroeconomic economic systems models employing predetermined elasticities and parameters (Condon et al., 2013; Berry, S., 2011). Such modeling makes it challenging to distinguish the short- and long-run impacts and specific marketing channels are not clearly delineated. Also, specific micro-channels associated with food and biofuel markets are not clearly defined or quantified.

2.2. Food price transmission

Regarding price transmission across developing countries, as summarized by Minot (2011), a large number of studies examine the degree of price transmission among markets within a country, however fewer studies examine the transmission across countries (see Abdulai, 2000 for Ghana; Lutz et al., 2006 for Benin; Negassa and Myers, 2007 for Ethiopia for example). Quiroz and Soto (1995) and Mundlak and Larson (1992) employed similar data but different models yielding different results: Mundlak and Larson found an average of 95% price transmission; Quiroz and Soto (1995) found no relationship between domestic and international prices for 30 of the 78 countries examined, and even in countries with a relationship, the convergence was generally very slow.

Minot (2011) analyzed the long-run relationship between domestic and international prices for 62 staple food prices in nine African countries to estimate the degree of price transmission. The results indicate a long-run relationship with world prices in only 13 of the 62 African food prices. Further the global food crisis was unusual in influencing African food prices. African countries could reduce vulnerability to fluctuations in world food prices by staple food self-sufficiency. Conforti (2004) provides evidence on price transmission in a number of agricultural markets. The work is based on a price database from 16 countries across African, Asian, and South American. Employing the same method as Minot (2011), results indicated there is a geographical regularity. African countries generally tend to exhibit a lower degree of price transmission.

By employing generalized method of moment, Lukas and Matthias (2013) indicate that landlocked countries experience less variability in grain prices, while African countries have more volatile prices. Further, trade policy restrictions seem to fail in limiting volatility transmission from international markets. A possible explanation is landlocked countries cannot rely on food imports, as much as coastal countries, and thus are less exposed to international price shocks (Lukas and Matthias, 2013).

In terms of U.S. food aid impacts on developing countries, Lentz et al. (2013) suggests local and regional procurement activities have no statistically significant relationship with either local price levels

or food price volatility. Tadesse and Shively (2009) study the impact of food aid on producer prices in three regions of Ethiopia for three commodities and find that shipments under 10% of domestic production have negligible effects on local prices. Levinsohn and McMillan (2007) estimate that price of wheat in Ethiopia, which was observed at \$193 per ton, would have in the absence of food aid been \$295 per ton. Gelan (2007) employs a CGE to argue that in the absence of food aid, food prices would rise by a maximum of 2.51% in Ethiopia.

In sum, 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. Regarding the methodology, except for Lukas and Matthias (2013) employing a generalized method of moments, research generally employs time series modeling. However, employing a standard time series analysis on each country for estimating individual country effects poses two empirical challenges (Pedroni, 2013; Mishra et al., 2014). First, many countries have a relatively short span of data available. For such countries, a standard time series analysis would not be reliable. Second, the data from many of the countries are fairly noisy, so even when a span of data is available, a conventional time series analysis for any one country may not be reliable. An alternative is to expand the panel dimension of the data to increase the reliability of the inferences (Pedroni, 2013; Mishra et al., 2014).

3. Econometric methodology

Considering the caveats of scenario simulation and partial/general equilibrium models, and the limitation of generalized method of moments and standard time series analysis on each country, an alternative time series model is employed. Specifically, a structural vector autoregression (SVAR) model is adopted. However, a time series model poses its own challenges. Developing countries' corn prices are likely interdependent and respond to common external shocks, which are not directly observable. In order to exploit the panel dimension, this form of cross sectional dependence should be considered for deriving inferences regarding the distribution of country responses. Furthermore, if the

dynamics are potentially heterogeneous among countries, it should be explicitly taken into account. Not addressing the heterogeneity and instead treating a country's dynamics as homogenous members of a pooled panel, risks inconsistent estimation and inference (Pesaran and Smith, 1995; Mishra et al. 2014).

Currently the literature on panel SVAR is scarce and the methodology developed requires specific assumptions about the timing of information flows and of responses. This would be hard to justify across a group of very diverse economies. As an example, the speed with which U.S. ethanol demand shocks affect local market prices are likely to differ by country. Furthermore, for estimation, the potential country linkage cross-sectionally via common global and regional shocks should be addressed (Mishra et al., 2014).

A heterogeneous panel SVAR methodology, developed by Pedroni (2013), is the appropriate method for uncovering the properties of the underlying structural dynamics. This is particularly the case when the panels are relatively short. Even a fairly small panels with 30 time periods and 20 cross sectional units do fairly well for responses to shocks by comparing it with panels of 100 to 200 time periods and 30 cross sections. Another advantage is the ability to consider the different lag periods for each individual country. The method allows loops over each country member and applies an information criteria separately for each country. The approach exploits orthogonality associated with structural VAR identification schemes. The result is a sample distribution of heterogeneous country responses to structural shocks, which accounts for both the dynamic heterogeneity as well as the cross sectional dependency. Specifically, let Z_{it} be the vector of U.S. ethanol demand, Q_t , and corn price, P_t , along with the i^{th} developing country corn price, PC_{it} , in time period t , $i = 1, \dots, N$ and $t = 1, \dots, t_i$. Parameters N and t_i are the number of developing countries and the length of the time period for country i , respectively. This results in $Z_{it} = (Q_t, P_t, PC_{it})'$, an unbalanced panel, which eliminate country specific fixed effects.

Estimation involves first computing the cross sectional averages of the differenced data, namely $\varepsilon_{it} = \Lambda_i \bar{\varepsilon}_t + \tilde{\varepsilon}_{it}$, where ε_{it} are the composite shocks, $\bar{\varepsilon}_t$ are the common shocks, $\tilde{\varepsilon}_{it}$ are the idiosyncratic, country specific shocks. Parameter Λ_i is a diagonal matrix of the country specific loadings, which reflect the relative importance of the common shocks for a particular country. Specifically, the orthogonal structural shocks are considered to be decomposed into orthogonal common and idiosyncratic components. For a detailed discussion refer to Pedroni (2013).

Applying this approach, the effects of U.S. ethanol and corn price shocks on developing countries' corn prices are estimated. Following Mishra et al. (2014), a SVAR model with restrictions is employed for each country. After a panel unit root test, the long-run structural form of the system can therefore be expressed as:

$$\begin{bmatrix} Q_t \\ P_t \\ PC_{it} \end{bmatrix} = A(1) \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3it} \end{bmatrix} \quad (1)$$

where Q_t and P_t denote U.S. ethanol demand and first differenced log transformed of real corn price, respectively, in time t , and PC_{it} is the first differenced log transformed real price of corn in developing country i . Realization ε_{1t} is the unexpected shock to output, Q_t , which is uncorrelated with ε_{2t} and ε_{3it} , the unexpected shocks to the U.S. domestic corn price and price of corn in developing country i , respectively. Examples are a demand shock resulting from a policy change in the U.S. Renewable Fuel Ethanol mandate or a shock to corn prices due to a U.S. Midwest drought. Note that

$$\varepsilon_{it} = \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3it} \end{bmatrix}.$$

The matrix $A(1)$ is 3×3 containing the long-run impulse responses, with zero upper diagonal elements. Equation (1) models U.S. ethanol demand as only affected by its own innovation. U.S. ethanol demand is currently supported by a federal ethanol mandate, which dictates the market level of ethanol demand. Thus, in contrast to a free market, ethanol is not based on the input price (the corn price). However, (1) does model U.S. corn prices affected by innovations in U.S. ethanol demand. With approximately 40% of U.S. corn funneling into refining ethanol, at least in the short run ethanol would impact U.S. corn prices (Qiu, et al., 2012; Hao, et al., 2015). Further, (1) models the corn prices in developing country i affected by both the innovations of U.S. ethanol demand and U.S. corn prices. The United States is the leading world producer and exporter of ethanol, and is a major world corn producer with 11% of its production destined for export. It is the leading corn exporter accounting for approximately 40% of world corn exports (U.S. Grains, 2015). U.S. corn prices will likely affect a developing country's corn price but not the reverse.

The U.S. ethanol demand is employed as the indicator for U.S. ethanol expansion. It is directly subject to U.S. government ethanol policy, so the innovation could capture ethanol market sensitively to policy shocks. An example is the Renewable Fuel Ethanol mandate, which requires U.S. transportation fuel contain a minimum volume of renewable fuels. Any change in the mandate, ethanol demand will change instantaneously, with a lag in ethanol production.

4. Data

The choice of the country panel is guided by the desire to limit attention to developing countries with availability of reliable monthly data on corn prices. This yields monthly real price series of corn adjusted by local inflation rates for 40 countries from January 2006 to January 2015, Appendix Table A.1 (FAO GIEWS, 2014). U.S. monthly corn prices are from USDA and ethanol consumption is from

the Energy Information Administration (EIA, 2014; USDA, 2014). Both price series are adjusted by CPI with 2005 as the base year.

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

The unit root tests, listed in Table 1, along with the logarithm transformed marketed ethanol, reject the presence of a unit root at the 1% significance level, when the price data are first differenced and logarithm transformed. These results indicate a Structural VAR model is appropriate to employ.

The impulse responses from (1) are 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 yearly ratio of U.S. corn donor over the domestic supply from 2006 to 2012 (World Food Program, 2015; FAOSTAT, 2015). Within this period, 22 countries out of 40 had zero U.S. aid. Food import dependency is indicated by the cereal imports dependency ratio, which equals cereal imports over domestic supply in 2011 (US Comtrade Database, 2015; FAOSTAT, 2015). All of the countries import corn. The coastal dummy variable, measuring geographic effects, is equal to 1 for a country which shares a border with another country and has a coast, and equals 0 for an isolated country which is not on a coast or does not boarder another country. Thus, Cabo Verda, an island country is defined as isolated rather than a coastal country (Appendix Table A.1.)

5. Empirical results

Results provide empirical evidences for understanding the impact of U.S. ethanol production transmission on food prices in developing countries. Impulse response functions are illustrated in Figure 1. Three spatial quartile lines are represented in the figures. The median, 25%, and 75% lines represent the median of the responses among the developing countries, 25% of the developing country responses below the line, and 75% falling below, respectively.

The impacts of U.S. ethanol demand on corn price shocks on developing countries' corn prices are markedly different from the U.S. corn price impacts, Figure 1. As illustrated in Figure 1a, a U.S. corn price shock will increase corn prices in developing countries. This increase is also persistent. In contrast, an ethanol demand shock has mixed results (Figure 1b). Approximately 50% of the countries will experience no increase or a decline in their prices. Appendix Table A.2 ranks the countries in terms of their order of susceptibility to U.S. corn price and ethanol shocks. From the rankings of variations in impulse responses no apparent underlying determinants are revealed.

In order to explore the determinants of this variation in impulse responses, the cross-section association 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 in the first month across the 40 developing countries were regressed on the geographic effects, food import dependency, and U.S. food aid dependency. Similarly the impulse responses for the second and third month were regressed over the three factors. The limited response observations, 40, and associated noise of both repressors and regressands motivate the significance level be expanded to 20%, and both multivariate (Table 2) and bivariate regressions (Table 3) presented (Mishra, 2014). As listed in Tables 2 and 3, results of the multivariate and bivariate regressions are generally similar in terms of signs, magnitudes, and significance.

As concluded by Cachia (2014) in developing regions, the maximum impact of a shock is generally felt within the first few months with the domestic adjustment varying by country. In this spirit, the first three post shock months are considered (Tables 2 and 3). In the first month, an F test for the multivariate regression of developing countries' corn price response to a U.S. ethanol shock is significant at the 1% level with an associated relatively high R^2 of 0.44. This multivariate regression along with campaign bivariate regression results indicate developing countries' corn price response to a U.S. ethanol shock is positively related to their food import dependency at a 5% significance level (Tables 2 and 3). This directly supports the hypothesis that countries with higher food import dependency will be more susceptible to the U.S. ethanol market. However, as indicated in Figure 1 along with the insignificance in Tables 2 and 3 for the second (only Table 2) and third month responses, the effects will dissipate through time. Note that the multivariate F statistic for a U.S. ethanol shock response is only significant at the 28% and 72% levels for the second and third months, respectively. This indicates even food import dependent countries have the ability to adjust to U.S. ethanol shocks in a relatively short time interval. However, there is a short-run impact that should be considered, particularly for food import dependency countries. This suggests country and international organizations policies toward addressing this short-run impact may be warranted. In particular, food import dependent developing countries appear to be more susceptible to biofuel shocks.

Developing countries' corn price response to a U.S. corn price shock is significantly weaker than the ethanol shock. The F statistics is only significant at the 5% level for second month. In terms of food import dependency, in the first and second month, at the 15% significance level there is only a positive relation in the bivariate regression (Table 3). As indicated in Figure 1, developing countries' corn prices are affected by a shock in U.S. corn prices, their dependency on food imports appears to influence, at least to a limited degree, their domestic corn price response. This result supports a 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 the World Bank cereal import dependency indicator was also considered with similar results in terms of signs and significance, which indicates the robustness of the results.

U.S. food aid influence on U.S. corn price and ethanol shocks is similar to the food import dependency. A marked exception is a negative coefficient, significant at the 5% level, on the bivariate regression for U.S. food aid dependency on U.S. corn price response in the third month. This negative influence coupled with a positive response in the first month indicates some *t*-adjustment in reestablishing equilibrium for the U.S. food aid dependency countries.

The difference in the U.S. ethanol shock and corn price shock, may be the result of a simultaneous relation among a U.S. ethanol shock, food dependency, and U.S. aid dependency. With ethanol absorbing the stocks of corn, less corn may be supplied in food aid and available for developing countries to import. This would suggest the stronger significance relation for a U.S. ethanol shock relative to a U.S. corn price shock. Figure 2 illustrates this relation over the 2005 to 2013 period. Both the percentage of U.S. corn exports and food aid declined as the percent ethanol marketed increases. Whether this is a correlation or some causal relation provides an opportunity for further research.

Regarding the continental and coastal effects, African countries are significantly positively affected at the 10% level by U.S. ethanol shock relative to other countries in the first month, which is consistent with the Cachia (2014)'s results. However, in the second month developing Latin American countries are affected significantly more by U.S. corn price shocks. Latin American countries are more susceptible to U.S. corn price shocks than African countries. The reason could be that Latin American developing countries have easier access to the U.S. market than African countries. Free trade agreements the U.S. has with a number of these Latin America developing countries leads to a more integrated market with price shocks easily transmitted. This result further supports the results of Cachia (2014), which indicates price transmission in Latin American countries are faster than in African. Price

transmission is generally slower and lower in markets such as Africa where price shocks are delayed by a longer marketing chain involving multiple market agents processing, packaging, shipping and distributing products (Cachia, 2014).

Even considering food import dependency and food aid dependency constant in the multivariate regressions, coastal countries seem to be more susceptible than isolated countries by a U.S. corn price shock. This follows from the literature, which suggests landlocked countries cannot rely as much on food imports, and thus are less exposed to international price shocks (Lukas and Matthias, 2013). However, the effect does not appear to affect response to U.S. ethanol shocks. This suggests a weak if any difference in the relation of international market shocks between coast and isolated countries. The trade relations and food dependency appear to play a larger role.

6. Conclusions and policy implications

Employing a heterogeneous panel SVAR model, the results offer insights into the linkage of developing countries' domestic corn prices to U.S. ethanol demand and corn prices. The hypothesis that U.S. ethanol demand and corn prices have differential impacts on developing countries' corn prices is supported by the results. Addressing this linkage fills a literature gap in empirically investigating this hypothesis.

The results provide an understanding of the mechanisms and consequences of U.S. ethanol demand transmission effect on food prices in developing countries. In particular, results reveal that the transmission effects of U.S. ethanol and corn price shocks are systematically stronger for countries with higher food import dependency and U.S. food aid. Although ethanol shocks appear to have a stronger impact, possibly due to its simultaneous relation with food import and U.S. food aid dependency. African countries appear to be more susceptible to these ethanol shocks. However, Latin American countries and coastal countries appear to more susceptible to U.S. corn price shocks.

For policy prescriptions, the determination of a typology of countries with respect to their exposure to shocks contributes toward improved understanding in designing food security policies. This understanding of empirical linkages of U.S. ethanol and corn markets to international corn prices will improve forecasts, which feed into early warning systems for food security (Cachia, 2014).

The bifurcation effects of ethanol and corn market shocks along with differential impacts for food importing and U.S. food aid dependency countries along with continental and coastal effects indicate the interlinking markets are far more complex than previous modeling efforts considered. This suggests one overarching policy may not be effective in efficiently addressing hunger issues. Consistent with the existing literature, results indicate that although landlocked countries are experiencing a higher volatility, when holding other factors constant, coastal countries are even more susceptible to a world economic shock, such as U.S. corn price shocks. Thus, the coastal countries should be paid no less attention when facing world economic shocks.

Trade rules negotiated at 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 general overarching. Such policies may provide a foundation for addressing global market shocks such as developing countries' biofuel policies. However, results indicate specific policies addressing the differing characteristics of developing countries are required for efficiently addressing any 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 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 (Ricardo Meléndez-Ortiz, foreword, 2011).

The U.S. and other countries along with international institutions aiming at reducing poverty and malnourishment in developing countries can take a precaution of the possible consequences of ethanol production in U.S. 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. The results indicate the impact of global shocks on a developing country's economy is not homogeneous across countries. Employing a heterogeneous panel SVAR is a first attempt at sorting out these impacts. Further research in this direction will unravel the complex nature of developing countries' response to global shocks.

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

Corn price(\$/kg)	United States	Total Developing Countries
Mean	0.16	0.36
Minimum	0.08	0.04
Maximum	0.26	8.48
Standard Deviation	0.05	0.55
Coefficient of Variation (Std/Mean)	0.31	1.52
Skewness	0.27	9.71
Kurtosis	2.03	124.29
Unit root test statistics after the first differenced log transformation	-7.02*	-17.02*
Number of Countries	—	40

Note: Augmented Dickey fuller test is employed to test U.S. corn price and the Z statistics value is reported. Fisher-type unit-root test based on both Phillips-Perron test and augmented Dickey-Fuller test are both employed, and the results both indicate unit root test are significantly rejected at the 1% level, and only adjusted z statistics value based on augmented Dickey-Fuller unit root test reported.

* denotes 1% significance level, indicating for all the transformed price variables the unit root hypothesis is significantly rejected.

Table 2. Results of multivariate regressions^a

	U.S. Ethanol Shock Response	U.S. Corn Price Shock Response
<i>In the first month</i>		
Food import dependency	0.020* (0.008)	0.001 (0.006)
U.S. food aid dependency	0.025** (0.014)	0.017^ (0.010)
African	0.007** (0.004)	0.001 (0.003)
Coastal	0.002 (0.005)	0.006** (0.004)
F Statistic Significance	0.0004	0.183
R-Squared	0.440	0.163
Adjusted R-Squared	0.374	0.064
<i>In the second month</i>		
Food import dependency	0.015 (0.014)	0.001 (0.003)
U.S. food aid dependency	0.013 (0.024)	0.009^ (0.006)
African	0.007 (0.006)	−0.004* (0.001)
Coastal	0.006 (0.008)	0.002 (0.002)
F Statistic Significance	0.284	0.049
R-Squared	0.134	0.239
Adjusted R-Squared	0.032	0.149
<i>In the third month</i>		
Food import dependency	0.016 (0.029)	−0.002 (0.003)
U.S. food aid dependency	−0.010 (0.050)	−0.006 (0.006)
African	0.016 (0.013)	0.000 (0.002)
Coastal	0.007 (0.017)	0.003^^ (0.002)
F Statistic Significance	0.716	0.132
R-Squared	0.059	0.183
Adjusted R-Squared	−0.052	0.087

^a Standard errors are in the parentheses with *, **, ^, and ^^ denoting 5%, 10%, 15%, and 20% level of significance, respectively. Food import dependency is the average of yearly ratio of cereal imports and domestic cereal supply. U.S. food aid dependency is U.S. corn 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.

Table 3. Bivariate regression results^a

	U.S. ethanol response	U.S. corn price response
<i>In the first month</i>		
Food import dependency	0.028* (0.007)	0.008 ^ (0.005)
U.S. food aid dependency	0.040* (0.011)	0.012^ (0.008)
Africa	0.008** (0.004)	0.001 (0.003)
Coast	−0.001 (0.005)	0.003 (0.003)
<i>In the second month</i>		
Food import dependency	0.020** (0.011)	0.004^ (0.003)
U.S. food aid dependency	0.020 (0.018)	0.006 (0.004)
Africa	0.007 (0.006)	−0.003* (0.001)
Coast	0.003 (0.007)	0.002 (0.002)
<i>In the third month</i>		
Food import dependency	0.014 (0.023)	−0.003 (0.003)
U.S. food aid dependency	−0.000 (0.036)	−0.011* (0.004)
Africa	0.015 (0.013)	−0.000 (0.002)
Coast	0.007 (0.013)	0.004* (0.002)

^a Standard errors are in the parentheses with *, **, ^, and ^^ denoting 5%, 10%, 15%, and 20% level of significance, respectively. Food import dependency is the average of yearly ratio of cereal imports and domestic cereal supply. U.S. food aid dependency is U.S. corn 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.

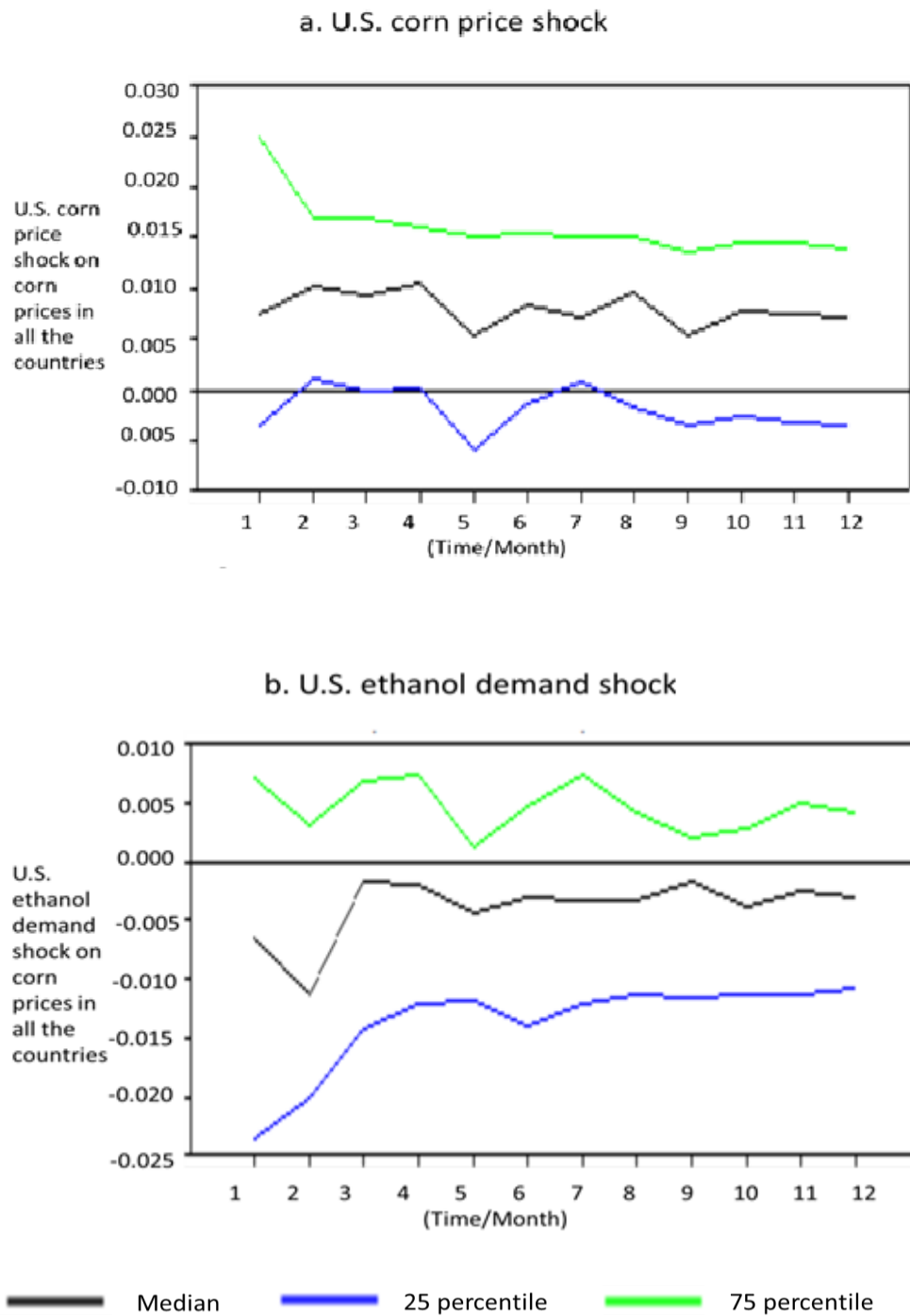
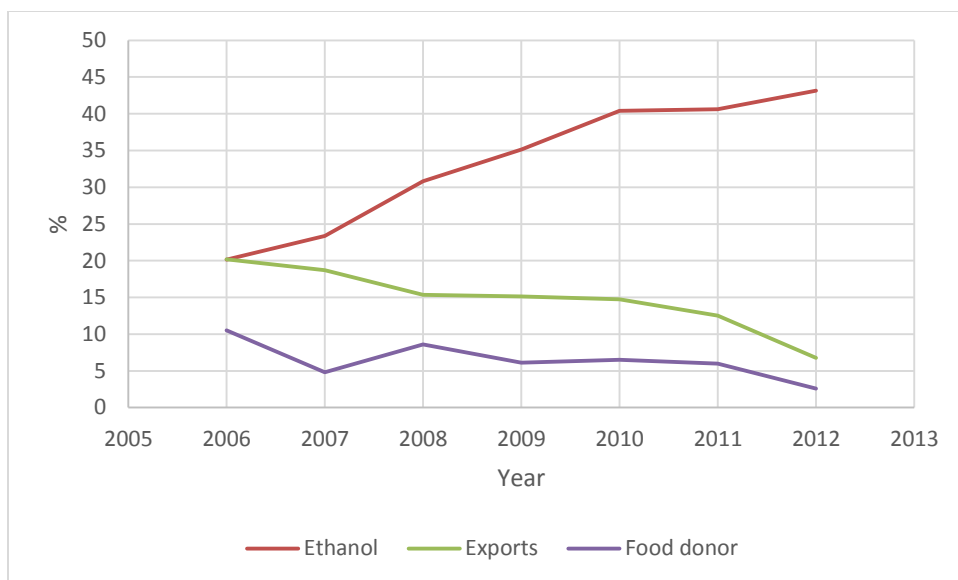


Figure 1. Developing countries' corn prices responses to U.S. corn price shock (a) and ethanol demand shock (b).



Note: <http://www.ers.usda.gov/data-products/feed-grains-database/feed-grains-yearbook-tables.aspx>
<http://www.wfp.org/fais/reports/quantities-delivered-report>
<http://www.indexmundi.com/agriculture/?country=us&commodity=corn&graph=exports>
<http://www.indexmundi.com/agriculture/?country=us&commodity=corn&graph=production>
 Percentage calculated by authors.

Figure 2. Percentage of U.S. corn used for ethanol, exports, and food aid (time 100)

Appendix

Table A.1. Country List

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

Table A.2. Country Order of Susceptibility

U.S. Corn Price Shock	U.S. Ethanol Shock
Benin	Democratic Republic of the Congo
Democratic Republic of the Congo	Central African Republic
Central African Republic	Ghana
Philippines	Togo
Togo	Colombia
Namibia	Benin
Kenya	Egypt
Morocco	Cameroon
Honduras	Panama
Egypt	Rwanda
Bolivia	Republic of Moldova
Argentina	Kenya
Brazil	Mexico
Cameroon	Cabo Verde
South Africa	Peru
Thailand	Niger
Niger	Honduras
Rwanda	Angola
Colombia	Haiti
Paraguay	Burundi
Chile	Ethiopia
Burundi	South Africa
Cabo Verde	Brazil
Zambia	Namibia
Ukraine	Thailand
Guatemala	Chile
Peru	Nicaragua
Nicaragua	Zambia
Dominican Republic	Philippines
Mozambique	Dominican Republic of the Congo
Angola	Guatemala
Panama	United Republic of Tanzania
Mexico	Argentina
United Republic of Tanzania	Mozambique
Ghana	Bolivia
Haiti	Chad
Chad	Ukraine
Malawi	Morocco
Ethiopia	Malawi
Republic of Moldova	Paraguay