Factors Explaining Crop Price Developments

- Time-Series Evidence for Developing and Developed Countries -

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ABSTRACT

The global hunger indices of 2008 and 2009 (Grebmer et al. 2008, 2009) point to persistently high levels of hunger and food insecurity and a worsening of the situation due to rising crop prices. At the same time, there is a lack of empirical knowledge on the demand- and supply-side determinants of crop prices. Given this situation, this paper estimates structural equation models by means of the three-stage least-squares estimator to identify the sensitivity of the price of three major crops (wheat, maize, and rice) in up to eight countries (India, China, Egypt, Thailand, Ecuador, Uruguay, the United States, and Australia) to global and country-specific crop demand and supply conditions. The evidence suggests that conclusions regarding the determinants of crop prices critically depend on the choice of crop and country. The nonexistence of a consistent and homogenous set of price determinants suggests that the stability and predictability of crop prices depends on country-specific domestic policies that target both the crop demand and supply side. The evidence also suggests that supply-side initiatives are likely to be more effective to this end.

Keywords – Agriculture, food prices, crop prices, simultaneous equations, three-stage least-squares

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1. Introduction

The global hunger indices of 2008 and 2009 (Grebmer et al. 2008, 2009) point to persistently high levels of hunger and food insecurity, especially in South Asia and Sub-Saharan Africa. For the latter regions, only marginal reductions in hunger have been realized since the 1990s, let alone for the regions' exposure to violent conflict. At present, past improvements in livelihood conditions and food security – however small they were – tend to be reversed given the adverse effects of the current global economic and financial crisis on real income and political stability. This development is further aggravated by the food price crisis of 2007-08, which reduced purchasing power by increasing the price of basic food items, especially of wheat, rice, and eatable oil.

The existing literature proposes numerous mutually reinforcing supply- and demand-side factors behind the global surge in agricultural and accordingly food prices (e.g., FAO 2008a, b; Headey and Fan 2008; Mitchell 2008; Oppedahl 2009, Loening, Durevall, and Birru 2009; Fortenbery and Park 2008). At the supply-side, higher agricultural prices are attributed to (1) production shortfalls from climate and environmental change and corresponding reductions in global crop stocks, (2) lower farm net returns and thus production disincentives due to high costs for energy-related agricultural inputs, (3) monetary policy induced exchange rate fluctuations and the depreciation of the US dollar, and (4) speculation in agricultural commodity markets. Closely related, the demand-side factors behind food price inflation include (1) changes in the utilization patterns of crops due to the rapid expansion of the global demand for biofuels, (2) rising population pressures in light of stagnant or contracting agricultural research and development expenditures, and (3) rapid economic growth and the associated shift in consumption to high-value agricultural and meat products.

Rising food prices are also perceived to be the consequence of commodity-based policies such as export restrictions, export bans and reduced or eliminated import tariffs and quotas on major crops.[1] Implemented to curb the transmission of higher international agricultural commodity prices to domestic markets and to stabilize domestic prices by increasing the domestic supply of agricultural commodities (Dawe 2008), these trade policy measures amplified the food supply shortages and thus the increase in international and national food prices through speculative hoarding and through adverse effects on the incentives of domestic producers to increase production (FAO 2008a). In addition to protective trade policy instruments, rising food prices are also perceived to be symptomatic for the inapplicability of the free market paradigm in poor and developing countries. Indeed, Magdoff and Tokar (2009) argue that rising food prices are the long-term consequence of a contraction in food supply, which results from the liberalization of food production and distribution under the free-market paradigm and from migration-driven labor shortages.

The dominant share of the existing literature identifies the determinants of food price developments by means of explorative or descriptive statistics. That is, the past has seen little systematic empirical research on the determinants of food prices. The lack of research is attributable to data limitations regarding the availability of time-series country-level crop data, but also to the fact that contracting

[1] See FAO (2009a, annex Table 1) for details on the policy responses of selected countries to rising agricultural commodity prices.

real global food prices from the 1980s to 2000s reduced the apparent policy relevance of related research. Exceptions are the studies of McNew and Griffith (2005), Fortenbery and Park (2008), and Loening, Durevall, and Birru (2009). In a study for Ethiopia, Loening, Durevall, and Birru (2009) emphasize the importance of international crop prices and exchange rate fluctuations as long-term drivers of agricultural prices. McNew and Griffith (2005) and Fortenbery and Park (2008) assess the extent to which ethanol production explains increases in US grain prices. In fact, McNew and Griffith (2005) provide evidence regarding the positive response of US grain prices to the opening of ethanol production plants in US regions, and Fortenbery and Park (2008) show that the US maize price is influenced by ethanol production and that the effect materializes through food, alcohol, and industrial (FAI) consumption.

Without doubt, food price developments reflect the effect of a multitude of factors, which need to be understood in order to identify effective strategies for creating conditions of stable international and domestic crop prices and - through these channels - food security. To this end, this paper aims to determine the sensitivity of the price of three major crops (wheat, maize, and rice) in eight countries to global and country-specific crop demand and supply conditions. The countries differ in terms of economic development and include India, China, Egypt, and Thailand as examples of transition economies, Ecuador and Uruguay as examples of urbanized economies, and the United States and Australia as examples of developed economies.

To anticipate the results, the evidence from structural equation models lends support that crop demand and supply factors affect crop prices. However, significant differences between crops as well as countries suggest that country-specific demand- and supply-side strategies are needed to accommodate developments in crop and accordingly food prices. These strategies have to take into account whether crop prices are mainly responsive to national (domestic) or international (foreign) factors.

The remainder of this paper is structured as follows. Section 2 presents the empirical model that is used to identify the determinants of crop prices. Section 3 describes the methodology and section 4 presents the data. Section 5 summarizes the empirical evidence. Reported are the determinants of crop supply and demand and the effect of crop demand and supply on crop prices. Section 6 seeks to explain crop price developments with changes in biofuels production. Section 7 concludes.

2. Empirical Estimation Framework

Closely related to Fortenbery and Park (2008), this paper presents a structural system of equations which link crop price developments to crop supply and crop demand conditions. The system is separately estimated for annual data on crop i (maize, wheat, or rice) in country j (Australia, United States, India, China, Egypt, Thailand, Ecuador, and Uruguay) and assumes the following form:

$$Z_{ij,t} = \alpha_{ij} + \beta_{ij}Z_{ij,t-1} + \gamma_{jk}X_{j,t-k} + \phi_j D_{jt} + \varphi_j Time_{jt} + \varepsilon_{ij,t}. \qquad (1)$$

Throughout this paper, α_{ij} is an intercept that is included to capture the effects of unobserved variables related to each crop i and country j and $\varepsilon_{ij,t}$ is an i.i.d. random variable with zero mean and constant variance, i.e., $N\sim(0,\sigma^2)$. Unless stated differently, D_{jt} represents dummy variables related to the occurrence of natural disasters such as storms, droughts, floods, or extreme temperatures at time t in country j.[2] Dummy variables are included to control for the effect of poor harvests on crop prices through crop supply shortages. In addition, the models incorporate a linear time trend or time dummy variables for selected years. The latter are included in order to capture the effects of more than proportional crop price changes at any point in time.

$Z_{ij,t}$ is a vector consisting of variables that are endogenous to the system and particular to each crop i in country j. It consists of information about the crop price (P_{ij}), crop consumption per capita (C_{ij}), crop supply per capita ($S_{ij,}$), and crop exports per capita ($Ex_{ij,}$).[3] The vector $Z_{ij,t}$ is correlated with the i.i.d. disturbances in the system's equations. In order to control for the endogeneity and omitted variable bias, the system of equations therefore also includes lagged values of Z_{ij} in instances when the endogenous variables are nonstationary and accordingly integrated of order one.[4]

Finally, X_j is a vector of exogenous variables that comprises country-specific information regarding energy prices, the real interest rate as measure of investment cost, the real effective exchange rate as measure of international competitiveness, and real per capita GDP as measure of per capita income. The following sections describe the structure of the system of equations in greater detail.

2.1 Crop supply equation

Equation (2) represents the structure of the time-series specification that is used to model the supply of crop i in country j at time t ($S_{ij,t}$).

$$S_{ij,t} = \alpha_{0,ij}+ \alpha_{1,ij}S_{ij,t-1}+ \alpha_{2,ij}P_{ij,t-1}+ \alpha_{3j}RIR_{j,t-1}+ \alpha_{4,ij}P^{W}{}_{ij,t-1}+\alpha_{5j}Oil_{j,t-1}+ \alpha_{6j}D_{jt}+ \alpha_{7j}Time_{jt}+ \varepsilon_{ij,t}. \quad (2)$$

Assuming that supply at time t represents production decisions of the past, the explanatory variables enter model (2) with a one-year lag. The autoregressive parameter α_1 models the effect of crop supply in period t-1 on crop supply in period t. P_{ij} approximates the price of crop i in country j. Assuming that prices follow a random walk and that production decisions are the outcome of rational behavior, the supply decision today is modeled to be determined by the price in period t-1. Assuming that prices positively correlate with the return on production, farmers are expected to increase crop supply in response to positive price developments so as to reap the benefit from higher returns. The price of crop i is accordingly expected to be positively related to crop supply.

[2] The model was also estimated with lagged values of the disaster variable D_{jt}. However, as the respective results do not differ from those with the contemporaneous variable, the lagged values are not further considered.
[3] Throughout this paper, consumption, supply, and exports are volume rather than value variables.
[4] The stationarity properties of the dependent variables are determined by means of Phillips-Perron tests. The respective test statistics are not reported but available on request.

RIR_j represents the real interest rate in country j, which is an opportunity cost of investing in agricultural productivity-enhancing research or rural infrastructure development. Infrastructure investment and ultimately crop production and supply are expected to decrease with the real interest rate. Because of implementation and effectiveness lags, crop supply is expected to be particularly responsive to past values of the real interest rate.

Crop supply is a composite measure of domestic production and imports. In order to account for the effect of trade on domestic supply, the supply equation also includes information on the real world price of crop i at time t-1 (P^W_{ij}).[5] It is expected that crop supply is lower for higher world prices and that implementation lags cause this relationship to be particularly pronounced for past values of the world price.

Oil_j is included to capture the effect of energy prices on crop supply. Energy prices are assumed to influence crop production and accordingly crop supply through their positive effect on fertilizer prices and irrigation costs (cf. FAO 2008a). The nature of the effect of rising fertilizer prices on crop production is ambivalent. Oil-price driven changes in fertilizer prices may induce farmers to balance the application of fertilizers (cf. Gulati and Narayanan 2003, p. 75), which could have a positive effect on crop production. However, crop production may also contract, especially if farmers do not adjust their fertilizer use, but try to recover higher fertilizer and thus production costs through higher procurement prices. In addition to fertilizer prices, the adverse effect of higher oil prices on crop production is likely to arise from oil price driven changes in irrigation costs and related crop yield and production effects. Oil prices may also adversely affect supply through their positive effect on transportation costs, which in turn influence imports. The effect is likely to be particularly pronounced for crop supply as it also includes imports. Again, the model assumes that farmers do not immediately respond to changes in oil prices because it takes time to adjust production even if energy price changes are directly transmitted to the farmers.

2.2 Crop consumption equation

Equation (3) represents the crop consumption model, i.e., the model that approximates the determinants of domestic demand for crop i.

$$C_{ij,t} = \beta_{0,ij} + \beta_{1,ij}C_{ij,t-1} + \beta_{2,ij}P_{ij,t} + \beta_{3j}Y_{jt} + \beta_{4j}D_{jt} + \beta_{5j}Time_{jt} + \varepsilon_{ij,t}, \quad (3)$$

where C_{ij} and P_{ij} abbreviate the per capita consumption and price level of crop i in country j, respectively, and Y describes per capita real income.

For maize and wheat, the consumption equation can be further subdivided into models explaining non-feed consumption related to food, seed, and industrial usage (FSI) and feed consumption.

[5] The value refers to the real international wheat, maize, and rice price index data as reported in the IMF World Economic Outlook (http://www.imf.org/external/pubs/ft/weo/2008/01/weodata/download.aspx). Model (2) does not directly include imports as imports are one component of crop supply.

Whenever data availability permits, model (3) is accordingly replaced with the following two specifications.

$$FSI_{ij,t} = \gamma_{0,ij} + \gamma_{1,ij}FSI_{ij,t-1} + \gamma_{2,ij}P_{ij,t} + \gamma_{3j}Y_{jt} + \gamma_{4j}D_{jt} + \gamma_{5j}Time_{jt} + \varepsilon_{ij,t}, \quad (4)$$

$$Feed_{ij,t} = \delta_{0,ij} + \delta_{1ij}Feed_{ij,t-1} + \delta_{2ij}P_{ij,t} + \delta_{3j}Livestock_{jt} + \delta_{4j}Poultry_{jt} + \delta_{5j}D_{jt} + \delta_{6j}Time_{jt} + \varepsilon_{ij,t}. \quad (5)$$

Equation (5) includes proxy variables of livestock and poultry production in order to approximate the crop consumption and price effect of demand shifts away from staples to cereal-intensive meat and dairy products. In order to capture the effects associated with the (rising) importance of livestock and poultry for the daily diet, the continuous variables in (4) and (5) are expressed in per capita terms.

2.3 Crop export equation

In addition to domestic demand, the analysis also seeks to identify the effect of foreign crop demand on crop prices. To this end, equation (6) is specified which models per capita export demand (Ex_{ij}) as a function of past per capita export levels of crop i, the per capita ending stocks of crop i in the rest of the world (ES^{ROW}), and the real effective exchange rate (Rer_j).

$$Ex_{ij,t} = \phi_{0,ij} + \phi_{1,ij}Ex_{ij,t-1} + \phi_{2,ij}P_{ij,t-1} + \phi_{3i}ES^{ROW}_{ij,t-1} + \phi_{4j}Rer_{jt} + \phi_{5j}D_{jt} + \phi_{6j}Time_{jt} + \varepsilon_{ij,t}. \quad (6)$$

Information on the per capita ending stocks of crop i in the rest of the world (ES^{ROW}_i) is included to capture the indirect effect of worldwide supply and demand conditions on domestic crop prices. The assumption is that higher ending stocks in the rest of the world suppress the exports of country i, vice versa.[6]

Finally, the real effective exchange rate (Rer_j) is included to approximate the nature of the relationship between international competitiveness and export demand. Real effective appreciations of national currencies are expected to have a negative effect on exports.

2.4 Crop price equation

Using the information from the demand and supply functions in equation (2) to (6), the price equation is specified as in (7) if domestic demand is approximated as aggregate consumption (3) and defined as in (8) if domestic demand is subdivided into feed and non-feed consumption.

$$P_{ij,t} = \varphi_{0,ij} + \varphi_{1,ij}P_{ij,t-1} + \varphi_{2,ij}S_{ij,t} + \varphi_{3,ij}C_{ij,t} + \varphi_{4,ij}Ex_{ij,t} + \varphi_{5j}D_{jt} + \varphi_{6j}Time_{jt} + \varepsilon_{ij,t}; \quad (7)$$

$$P_{ij,t} = \varphi_{0,ij} + \varphi_{1,ij}P_{ij,t-1} + \varphi_{2,ij}S_{ij,t} + \varphi_{3,ij}FSI_{ij,t} + \varphi_{4,ij}Feed_{ij,t} + \varphi_{5,ij}Ex_{ij,t} + \varphi_{6j}D_{jt} + \varphi_{7j}Time_{jt} + \varepsilon_{ij,t}. \quad (8)$$

[6] In addition to ending stocks, model (6) was also estimated by using information on crop production, exports, and consumption in the rest of the world. The respective results compare well with those presented in this paper.

Given the predictions of standard demand- and supply-side analysis, the price of crop i in country j (P_{ij}) is expected to be negatively affected by supply conditions ($S_{ij,t}$) and positively by demand conditions (C_{ij}, FSI_{ij}, $Feed_{ij}$, and Ex_{ij}).

3. Methodology

Consistent with Fortenbery and Park (2008), the system of equations in (2) to (8) includes contemporary values of the crop price and per capita crop supply, exports, and consumption (i.e., total, feed, and FSI consumption) as endogenous variables. The exogenous variables include lagged values of the per capita ending stocks of crop i in the rest of the world, the oil price, and the real effective exchange rate as well as contemporary values of the per capita income level at time t. Other exogenous variables are dummy variables of weather-related disasters at time t[7], a time trend, or time dummies. In order to conserve on degrees of freedom, dummy variables are only retained in the system if they have a significant effect on crop prices, demand and/or supply. The final structure of the system of equations accordingly differs between crops and countries.

In order to determine whether the system of equations is identified for the set of endogenous and exogenous variables, the order and rank conditions are computed. The order condition for identification is checked by counting the number of endogenous explanatory variables and instruments for a single equation. The rank condition is calculated by means of the STATA procedure developed by Baum (2007). The evidence suggests that all system equations satisfy the order and rank condition and that the system as such is thus identified.[8]

This paper treats the system of equations as a time-series specification that is estimated by means of the three-stage least-squares estimator (3SLS). Panel estimations are not carried out in view of pronounced crop and country heterogeneities, which are likely to invalidate the panel assumption of parameter homogeneity. Being a generalization of the two-stage least-squares (2SLS) method, 3SLS is preferred to 2SLS as it has an efficiency advantage over 2SLS in the presence of endogeneity. Moreover, 3SLS controls for the correlation of the system equations' error terms and the correlation of the explanatory variables with the error terms (see Fortenbery and Parker 2008 and the reference therein). As the time series dimension of the paper is comparatively short (see section 4), this paper reports 3SLS estimators that are computed by controlling for small sample characteristics.

4. Data

The system of equations is estimated by using, among others, information from the Foreign Agricultural Service's Production, Supply, and Distribution (PSD) database of the United States Department of Agriculture (USDA).[9] This database contains country-specific information on (1) field crops such as the volume of crop production, supply, consumption, and export as well as (2)

[7] The results are robust to the inclusion of disaster variables that are lagged one period.
[8] The respective results are available on request.
[9] See http://www.fas.usda.gov/psdonline/psdQuery.aspx.

livestock such as the number of cattle and swine heads or the quantity of broiler meat produced. The PSD database introduces supply as the sum of crop production, imports, and beginning stocks. As this definition implies a significant and positive correlation between supply, production, and stocks, the present analysis cannot control for the possible effects of speculative hoarding on crop prices (cf. FAO 2008a).

Macroeconomic indicator variables such as the consumer price index, GDP deflator, real (effective) exchange rates, and real per capita GDP are compiled from the Economic Research Service of the USDA.[10] Nominal exchange rate data are available from the International Financial Statistics of the International Monetary Fund. The exchange rate and inflation data are used to express the country-specific data in terms of real national currencies. In the case of Thailand, the real exchange rate (per USD) is also used as proxy variable of international competitiveness as information on the real effective exchange rate is unavailable. The oil price – our measure of energy prices – refers to an OPEC average basket price ($/b).[11] The price is expressed in terms of real national currency.

Crop-specific prices are approximated with crop producer prices, with the respective information being collected from the FAO PriceSTAT database, the FAO-GIEWS database, and the OECD-FAO Agricultural Outlook 2009-2018.[12] Crop prices are expressed in national currencies to control for the fact that poor households mainly consume domestically produced food crops, paid for with local currencies. If one would express the country-specific prices in US dollar, the price fluctuations would be more pronounced as the US dollar depreciated against most currencies during the last years (cf. Headey and Fan 2008). For similar reasons, the crop price data are adjusted for inflation by using country-specific information on the consumer price index for food items.[13]

Information on the occurrence of natural disasters in terms of extreme temperature, droughts and floods, or storm is collected from the EM-DAT database. Although very comprehensive, care must be exercised when interpreting the EM-DAT results as the underlying database does not contain a complete representation of disasters and the costs involved. This is because the database builds on information provided by individual countries, and these certainly differ in terms of quality and completeness. Given this limitation, the present paper does not attempt to distinguish disasters by severity, but only captures crisis events in a given year and country with a binary dummy variable that equals one if a disaster occurred and zero otherwise.

Common to the datasets is the annual frequency of the data. Unfortunately, the use of annual data is disadvantageous to the extent that it reduces sample variability, which may in turn preclude the detection of significant relationships. As higher frequency data is unavailable, this shortcoming can only be acknowledged. The time-series dimension of the data differs widely across crops and countries. Dependent on the selected country and crop, data availability extends to the period 1970-2008 in the ideal case, but can also be as short as 1992-2008. In order to ensure the optimal use of

[10] See http://www.ers.usda.gov/Data/Macroeconomics/.
[11] See http://www.opec.org/library/Annual%20Statistical%20Bulletin/pdf/ASB2008.pdf for details.
[12] See http://faostat.fao.org, http://www.fao.org/giews/pricetool/, and http://stats.oecd.org/.
[13] Ideally, the analysis would employ crop-specific price indices. Unfortunately, such information is unavailable. However, as the study emphasizes the results from crops that account for a substantial part of the countries´ crop portfolio, crop price inflation is likely to be reflected in the consumer price index for food items.

all information, the time-series dimension of the empirical specifications is allowed to vary across countries and crops.

Countries differ in terms of agro-ecological conditions and these dissimilarities account for cross-country differences in the types of crops covered. For instance, information related to rice is available for the major rice-producing and -consuming countries such as India and China, but not for Ecuador. Most likely than not, data availability extends to crops that account for a relatively large share of a country's crop consumption portfolio. This implies however that the analysis is likely to be biased towards crops for which demand and thus consumption is (relatively) price inelastic.

In addition to country differences in the type of crops covered in the analysis, there are also country differences in the type of livestock or poultry covered. The country differences reflect the effect of religion and culture on meat-related consumption patterns, which in turn affects data availability. In most instances, livestock refers to the number of heads of cattle or swine production and poultry describes the volume of broiler production in country j.

5. Empirical Results

This section summarizes the empirical evidence regarding the factors behind crop price developments. The results are presented by crop in Table 1 for wheat, Table 2 for maize, and Table 3 for rice. In order to facilitate the interpretation of the coefficient estimates as (short-run) elasticities, the evidence refers to specifications that express the dependent and almost all independent variables in the system of equations in logarithmic terms. The exceptions are the real interest rate and the dummy variables.[14]

As regards the dummy variables, the analysis mainly presents results from specifications that exclude disaster dummies because these frequently do not explain crop supply, crop demand, crop export, and/or crop prices. The statistical insignificance could be due to the time-bounded and cyclical occurrence of disasters and due to the fact that weather-related events frequently take place in months when the farm produce is already harvested. The absence of significant disaster effects is particularly striking for Australia. Being affected by a prolonged period of below average rain across southwest and southeast Australia since 1997 (Government of Australia 2009), the evidence does not lend support to the existence of a significant drought-related effect on domestic supply, domestic exports, or the world's stock level of wheat or maize.

The remainder of this section first reviews the effect of crop prices on crop supply and crop demand (equation 2-5) and then summarizes the effect of crop supply and crop demand on crop price (equation 7-8). The evidence from equation 2-5 will be used to identify the channels through which supply and demand influences prices. As indicated, the demand and supply variables are expressed in per capita terms. As the empirical results are robust to the normalization of the variables by population, the per capita reference will be dropped from the following discussion.

[14] As the real interest rate occasionally also assumes negative values, it is not expressed in terms of logarithm to avoid a loss of information.

5.1 Effect of crop price on supply and demand

This section summarizes the effect of crop prices on crop supply and demand. The discussion mainly emphasizes the results that are associated with significant coefficient estimates. Unfortunately, a comprehensive set of significant coefficient estimates does not exist, which in turn precludes a sound comparison of the magnitude of the coefficients across different crop types and countries.

5.1.1. Effect of crop price on crop supply

Conclusions regarding the effect of crop prices on crop supply differ across countries and crop. Significant effects of crop prices on crop supply mainly prevail in estimations for wheat. Consistent with the predictions of standard supply theory, the evidence for large wheat-producing economies such as India and China suggests that wheat supply increases with the (lagged) price of wheat. Ambiguous results prevail for maize. Significant effects only prevail in estimations for Ecuador and Thailand. However, while maize supply increases in response to higher prices in Thailand, it contracts in the case of Ecuador. As regards rice supply, support for the existence of significant price-supply relationships only prevail for India, with rice supply expanding in response to higher prices. The general absence of significant relationships between crop price and supply could be the result of marginal land farming, which is characterized by limited scope for yield and productivity increases.

5.1.2. Effect of crop price on domestic crop demand

Similar to supply, conclusions regarding the existence of significant relationships between price and (FSI and feed) consumption depend strongly on the choice of crop and country. As regards wheat, higher wheat prices lower wheat feed consumption in Thailand, the United States, and Australia, but stimulate it in India. The result for India can be attributed to the existence of maximum retail prices, which limit the pass-through of higher crop producer prices to consumers. Considering FSI wheat consumption, it contracts in response to higher wheat price levels in Thailand and Australia, but expands in China. For the remaining countries, FSI and feed wheat demand appear to be price inelastic.

The empirical support for the price inelasticity of demand is even more pronounced for maize and rice given that the price effect on both feed and FSI consumption is insignificant for most countries. Support for the existence of a significant relationship between crop price and consumption is confined to the case of (1) feed maize consumption in the United States and (2) total rice consumption in the United States and Australia. For these cases, consumption moves inversely with the respective crop price.

5.1.3. Effect of crop price on exports

Finally, the evidence suggests that exports are determined by domestic crop prices. However, the nature of the effect differs between countries and crops, and depends on whether the point of reference is the contemporary crop price at time t or the lagged crop price at time t-1. In particular, wheat exports increase with wheat prices at time t for India, Thailand, and the United States. At least for India and Thailand, the export-price relationship could be indicative for the role of prices in equilibrating demand and supply given the existence of significant and positive interdependencies between exports, consumption, and supply at time t.[15] Considering the export effect of lagged wheat prices, wheat exports of China and the United States decrease with wheat prices at time t-1, which could reflect stock adjustments through exports in response to changing supply and demand conditions. In contrast, wheat exports of Australia increase with past wheat prices.

As concerns the relationship between rice and exports, significant effects prevail in estimations for India, Thailand, and Egypt, with exports contracting in response to higher prices at time t, but expanding in response to higher prices at time t-1. Future research may want to assess whether these relationships are conditioned by cyclical price-demand-supply conditions and thus driven by the principle of time-series mean reversion.

Considering maize, the evidence suggests that maize exports positively depend on the contemporaneous and lagged values of the price of maize. Significant effects are reported for India, China, Ecuador, and Australia. Unfortunately, data availability constraints preclude assessments regarding the question whether the positive relationship between maize exports and price reflect the biofuels-related increase in the global demand for maize.

5.2 Effect of supply and demand on crop price

This section summarizes the effect of crop-specific supply and demand conditions on the price of crop i. The evidence shows that price developments are frequently best explained with time dummy variables rather than with crop demand and supply. When significant, prices appear to be particularly responsive to consumption, followed by supply and export. Except for this similarity, the empirical evidence points to pronounced heterogeneities in the results and explanatory power of the models across different crops within countries and across similar crops between countries.

5.2.1 Effect of domestic crop supply on crop price

Considering the results from estimations with significant results, crop prices decrease in response to higher crop supply levels. Being consistent with the predictions of standard microeconomic supply theory, this negative relationship is observed for wheat in the case of China and the United States,

[15] The correlation coefficients between exports and consumption or supply are not reported, but available on request.

for maize in the case of India and Thailand, and for rice in the case of India, Egypt, and the United States. Surprisingly, higher supply is associated with an increase in the price of rice in China and an increase in the price of wheat in Australia, Thailand, and Uruguay.

At least in India, the absence of a significant relationship between wheat supply and wheat price is likely to be driven by the country's agricultural price policy, which embraces minimum support prices (MSP). MSPs assure farm producers that the Government will purchase all harvest at a specified MSP if the market price falls below the MSP. The MSP at time t is announced by the Central Government prior to the sowing period t and thus stimulates domestic cereals production largely independent from market forces (Vyas 2007).

5.2.2 Effect of domestic crop demand on crop price

As concerns the price effect of consumption, FSI and feed consumption do not affect the price of maize and wheat in most specifications, with significant effects being confined to maize in India and the United States and wheat in Australia and the United States.[16] The evidence suggests that higher demand for both maize-related FSI and feed products exercises upward pressure on the price of maize in India, but downward pressure in the case of the United Sates. The negative relationship between price and consumption also prevails for wheat consumption in Australia and the United States. The US-related finding differs from the evidence in Fortenbery and Park (2008) who predict a positive demand-price relationship at least for maize. The difference in the result may reflect cross-study dissimilarities in the frequency and time period of the data, with Fortenbery and Park (2008) using quarterly data from 1995 to 2006.

Turning to the price effect of rice consumption, the evidence suggests that rice prices increase with rice consumption in India and Egypt, but decrease in China, the United States, and Australia. Assuming that the predictions of standard demand-supply relationships hold, the negative price effect of consumption could arise because (1) supply leads demand or (2) supply regulates demand through prices. Support for this hypothesis is provided by (1) the significant and positive cross-correlation between lagged values of rice supply and contemporary values of rice consumption and (2) the significant and negative cross-correlation between lagged values of rice supply and contemporary rice prices.[17]

[16] Because FSI and feed consumption do not affect the price of maize and wheat in most specifications, estimates are also derived for the aggregate consumption variable (equation 3). The respective evidence compares well with that from estimations for the FSI and feed sub-components of consumption. The only exception prevails for China, for which the wheat price increases with total wheat consumption. The respective results are not reported, but available on request.

[17] The correlation coefficients are not reported, but available on request.

5.2.3 Effect of crop exports on crop price

As for the previous findings, the price effect of exports differs between crops and countries. Referring to the price effect of wheat exports, higher exports in China, Thailand, and the United States are associated with higher prices. While the US price of wheat increases in response to higher wheat exports, the US price of maize does not depend on maize exports. This finding contrasts the evidence in Fortenbery and Park (2008), who point to a positive effect of maize exports on the price of maize. In Australia and Ecuador, significant export effects on price only prevail for wheat and maize, respectively, with increases in exports being associated with lower prices.

Wheat and maize exports from India by and large do not affect Indian crop prices as poor international competitiveness due to low productivity constrains external demand (Vyas´2007). Similar to India, the price of rice in Thailand is also inversely related to the country’s rice exports. However, rice export levels in the United States and Egypt are predicted to raise the countries’ price of rice. This could be the consequence of increased domestic and foreign competition for domestically produced rice.

5.2.4 Transmission mechanisms

Using the evidence in Table 1 to 3, the remainder of this section seeks to identify the factors through which crop demand and supply affect crop prices. The review is confined to those cases where crop prices are predicted to move with the demand and supply components. Starting with supply, there is weak evidence that supply affects prices through oil prices and real interest rates. Significant and positive oil price effects are obtained for the production of wheat in Uruguay and Australia and the production of rice in the United States. Although the result is indicative at best, it suggests that higher oil prices may strengthen efforts towards cost effective production through, for example, the more effective use of crop input factors. Given the weak empirical support for the existence of a significant relationship between oil and crop prices, the present results differ from those of the FAO (2008a) according to which higher energy prices increase food prices through their positive effect on the price of fertilizer, chemicals, and transportation.

Similar to the oil price, the real interest rate does not have a significant effect on crop supply. The exception arises with respect to the United States, for which real interest rates are found to have a negative effect on rice supply. As rice farming in the United States includes capital-intensive specialized equipment, lasers, and computers[18], higher real interest rates may reduce rice supply by crowding out investment in rice infrastructure.

As regards the effect of international prices on crop supply and ultimately output prices, statistically significant effects only prevail in the estimation for wheat in Uruguay. There, higher international prices appear to increase wheat supply, and through this channel domestic prices.

[18] See http://www.usriceproducers.com/.

There are only very few cases when the determinants of domestic demand also affect crop prices. For instance, demand appears to affect crop prices through per capita consumption in the case of maize in India, with higher per capita consumption being associated with lower consumption and – given the positive effect of FSI consumption on maize prices - accordingly lower maize prices. Higher per capita income levels thus may induce consumers to substitute away from rice. Turning to feed consumption, the evidence suggests that livestock production affects the price of maize through feed demand in the case of India and the United States. However, while the price of maize increases in response to per capita livestock production in the case of India, it contracts in the case of the United States. The result for the United States differs from the evidence in Fortenbery and Park (2008), who report a positive and significant effect of cattle on feed demand and accordingly the price of maize, although for a different measure of cattle.

The price effect of exports appears to be mainly driven by the degree of international competitiveness. Currency appreciations lower the exports of rice in India, wheat in China, and maize in Ecuador, but are associated with higher rice exports in Egypt. The effect for Egypt is inconsistent with theoretical predictions, but could arise if the absolute deterioration in international competitiveness does not imply relative deteriorations. The negative export effects of real appreciations are associated with lower prices in India and Ecuador, but higher prices in China and Egypt. Finally, exports are also influenced by the ending stocks of crop i in the rest of the world, although in only some cases. In particular, exports of wheat increase with the ending stocks in estimations for Thailand, the United States, and Australia. In comparison, exports of maize in Ecuador and rice in Egypt are inversely related to the ending stocks of the respective crops in the rest of world. Consistent with expectations, higher stocks abroad thus seem to reduce the need to procure crops from abroad.

6. Biofuels Production and Crop Prices

Section 1 introduced rising biofuels demand as one factor behind food price inflation. The argument is that the increase in biofuels demand caused a surge in food prices through (1) fiercer market competition for biofuels-related agricultural commodities (FAO 2008b), (2) spillover effects to other food commodities through demand and substitution effects, and (3) competition for resources used for food production. Ideally, the FSI consumption equation (4) would also capture the effect of biofuels demand or production on crop prices. However, as information on related variables is only available as of 2000 for relatively few countries, this approach is infeasible. Instead, this paper tests for the existence of a relationship between biofuels and (1) crop prices or (2) crop consumption by means of pairwise cross-correlation coefficients. The results are presented in Table 4 for biofuels production.[19] Anticipating the results, there is little support that the link between biofuels production and crop prices is conditioned by relationships between biofuels production and crop consumption.

[19] Because biofuels demand significantly and positively correlates with biofuels production, separate results for biofuels demand are not reported.

The nature of the relationship between crop prices and biofuels production differs between countries and between crops. In particular, biofuels production is significantly and positively related to the price of wheat and rice in China, positively related to the price of wheat, maize and rice in Thailand and the United States, positively related to the price of rice in Australia, but negatively related to the price of wheat and maize in India. The unexpected inverse relationship between biofuels production and the price of wheat and maize for India may reflect the strong effect of price regulation in India. If true, the positive relationship between maize FSI consumption and the price of maize in India (Table 2) may not reflect demand-side pressures from rising biofuels production. Finally, biofuels production does not directly correlate with crop prices in the case of Ecuador, and Uruguay.

The remainder of this section asks whether significant relationships between biofuels production and crop prices are associated with significant linkages between biofuels production and crop consumption or supply. Considering China, the positive relationship between biofuels production and wheat and rice prices corresponds with negative linkages between domestic wheat and rice consumption and wheat and rice supply. Although causal relationships cannot be determined at this stage, the evidence from China thus lends cautious support that increases in wheat and rice prices could be amplified by a biofuels-related contraction in wheat and rice supply. For India and Thailand, positive linkages between crop prices and biofuels production are associated with positive relationships between biofuels production and crop consumption. That is, biofuels production may drive crop prices through crop demand effects. Things are less straightforward for the United States. Although the price of wheat and biofuels production is positively related, biofuels production negatively correlates with wheat demand. This may reflect the substitutability of wheat and maize given that biofuels production positively correlates with maize consumption. The positive relationship between the price of wheat and biofuels production could thus indirectly arise from the biofuels-related change in the demand for maize. Comparable relationships prevail for Australia, with biofuels production being positively and negatively associated with wheat and maize consumption, respectively. However, biofuels-related changes in wheat and maize demand do not co-vary with the price of wheat and maize.

Although these results are tentative, it appears that biofuels production is related to crop prices. The direction of the causal relationship is not yet established and spillover effects across countries from trade in biofuels are not yet covered. More respective research with longer time series data is required.

7. Conclusion

This paper has used crop price and crop output data to identify and analyze the source of crop price developments during the last two decades. In contrast to existing work on the determinants of food price developments, this paper explicitly focused on the determinants of crop price movements for three crops in 8 differently developed countries. The evidence from a structural system of equations shows that demand and supply conditions affect crop prices and that the effects arise from macroeconomic variables like real per capita income, the real interest rate, or the real effective exchange rate. However, conclusions regarding the nature and significance of the underlying relationships critically depend on the choice of country and crop. The absence of a consistent set of factors driving crop prices suggests that country- and region-specific strategies are needed to control movements in crop prices and accordingly food prices.

The respective strategies should target both the crop demand side and supply side, although supply-side initiatives are likely to be more effective in stabilizing or even reducing crop prices. Supply-side strategies for improving agricultural sector performance should promote investment in agricultural research and extension. This must include efforts (1) to strengthen the linkages between agricultural extension and research and (2) to improve the institutional capacity of providing agricultural research and extension services. Given regional differences in terms of, for instance, (1) the policy environment, (2) the capacity of potential service providers, and (3) the type of farming systems and the market access of farm households (cf. Raabe 2008 and the references therein), these strategies should be designed such as to best fit particular needs, purposes, and targets (Birner et al. 2006). If effective, supply-side strategies can probably also accommodate the biofuels-related increase in crop prices.

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Table 1: Three-Stage Least-Squares Estimates for Wheat
Table 1A: Five equations system with FSI and feed consumption

		United States		Australia		India		China		Thailand	
Price eq.	Wheat price (t-1)	0.520	***	0.558	**	0.424	*	0.367		0.432	***
		(0.087)		(0.233)		(0.254)		(0.279)		(0.159)	
	Supply (t)	-0.701	**	1.120	***	-0.173		-1.596	**	0.465	**
		(0.290)		(0.383)		(0.335)		(0.610)		(0.250)	
	FSI (t)	-2.535	***	-0.130		0.426		8.960		0.148	
		(0.464)		(0.268)		(0.266)		(5.703)		(0.150)	
	Feed (t)	0.016		-0.380	***	-0.041		0.156		-0.052	
		(0.075)		(0.108)		(0.059)		(0.163)		(0.076)	
	Export (t)	0.682	***	-1.039	***	0.023		0.086	*	0.639	***
		(0.190)		(0.33)		(0.019)		(0.045)		(0.174)	
	Trend					-0.009	**	0.043		-0.060	**
						(0.004)		(0.058)		(0.023)	
	Flood dummy (t)									0.080	**
										(0.035)	
	Constant	-2.822	***	0.795		5.986	*	24.162	*	13.358	***
		(1.010)		(0.983)		(3.168)		(13.287)		(3.307)	
Supply eq.	Supply (t-1)	0.751	***	-0.060		0.327	**	1.088	***	0.073	
		(0.079)		(0.162)		(0.131)		(0.087)		(0.266)	
	Wheat price (t-1)	0.102	***	0.233		0.295	**	0.140	**	-0.430	
		(0.035)		(0.196)		(0.128)		(0.074)		(0.264)	
	Oil price (t-1)	0.001		0.005	***	0.0001	***	0.0002		0.0000	
		(0.001)		(0.002)		(0.0000)		(0.0001)		(0.0000)	
	Real interest rate (t-1)	-0.003		0.014		0.023	***	-0.002		0.006	
		(0.004)		(0.014)		(0.008)		(0.002)		(0.004)	
	Int'l wheat price (t-1)[A]			-0.899	*	-0.323	**	0.171		0.140	
				(0.476)		(0.156)		(0.136)		(0.313)	
	Trend							-0.005	***	0.047	***
								(0.002)		(0.017)	
	Drought dummy (t)			-0.248	**						
				(0.116)							
	Constant	-0.839	***	0.428		-3.910	***	-1.066	**	-1.783	
		(0.215)		(1.141)		(1.202)		(0.429)		(1.785)	

- Table 1A continued on next page -

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FSI eq.	FSI (t-1)	0.863 ***	0.111	0.118	0.724 ***	0.610 ***
		(0.094)	(0.166)	(0.187)	(0.127)	(0.207)
	Wheat price (t)	-0.018	-0.268	0.196	0.030 ***	-0.479 **
		(0.017)	(0.212)	(0.165)	(0.010)	(0.227)
	Per capita income (t)	-0.021	0.242	0.049 **	0.005	-0.502 **
		(0.035)	(0.156)	(0.022)	(0.010)	(0.242)
	Trend				-0.004	0.050 **
					(0.002)	(0.020)
	Constant	-0.014	-2.904	-4.641 ***	-0.854 ***	6.471 **
		(0.531)	(2.606)	(1.675)	(0.306)	(3.128)
Feed eq.	Feed (t-1)	0.101	0.486 ***	0.837 ***	0.602 **	-0.509 *
		(0.157)	(0.145)	(0.165)	(0.296)	(0.257)
	Wheat price (t)	-1.874 ***	-0.585 **	1.761 ***	-0.309	-2.924 ***
		(0.536)	(0.277)	(0.625)	(0.681)	(0.666)
	Cattle heads (t)	3.161 ***	-0.659	3.011 ***	1.154 **	
		(1.051)	(0.945)	(1.378)	(0.546)	
	Swine heads (t)	0.105	-0.983		-3.304 **	
		(1.361)	(0.770)		(1.618)	
	Broiler (t)					0.713 **
						(0.313)
	Trend				0.052 *	0.054 ***
					(0.031)	(0.019)
	Constant	12.258 ***	0.452	-8.228	-0.481	18.205 ***
		(4.56)	(1.906)	(7.539)	(4.122)	(4.792)
Export eq.	Export (t-1)	0.460 ***	0.146	0.600 ***	0.591 ***	-0.150
		(0.149)	(0.151)	(0.173)	(0.137)	(0.174)
	Wheat price (t)	0.598 ***		5.899		1.700 ***
		(0.191)		(4.592)		(0.296)
	Wheat price (t-1)	-0.296 *	0.364 **	-4.085	-2.860 **	0.169
		(0.160)	(0.172)	(3.901)	(1.122)	(0.366)
	REER (t-1)	-0.273	0.041	-0.409	-3.458 ***	0.202
		(0.312)	(0.207)	(1.497)	(1.152)	(0.235)

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Export eq.	Ending stocks ROW (t-1)	0.315 *	0.337 *	0.095	-0.343	0.360 **
		(0.173)	(0.176)	(1.948)	(1.127)	(0.164)
	Trend				0.088 *	0.056 ***
					(0.052)	(0.014)
	Flood dummy (t)					-0.106 **
						(0.053)
	Drought dummy (t)		-0.239 **			
			(0.113)			
	Constant	-0.301	-1.129	-17.309	29.361 ***	-25.143 ***
		(1.381)	(1.199)	(41.579)	(7.532)	(5.462)

Goodness of fit statistics	Obs	F-stat	R-sq	Obs	F-stat	R-sq	Obs	F-stat	R-sq	Obs	F-stat	R-sq	Obs	F-stat	R-sq
Price eq.	38	55.63***	0.89	28	9.00***	0.55	24	4.45***	0.55	22	3.75***	0.45	16	10.87***	0.88
Supply eq.	38	38.44***	0.82	28	3.13***	0.18	24	7.43***	0.60	22	57.85***	0.96	16	53.23***	0.97
FSI eq.	38	111.91***	0.91	28	6.08***	0.45	24	3.30**	0.34	22	503***	0.99	16	29.22***	0.91
Feed eq.	38	6.18***	0.43	28	9.30***	0.55	24	14.65***	0.65	22	5.36***	0.56	16	8.95***	0.77
Export eq.	38	10.59***	0.46	28	4.03***	0.41	24	2.99**	0.29	22	48.43***	0.94	16	31.30***	0.96

Note: Standard errors are in parentheses. ***, **, * denote the statistical significance at the 1%, 5%, and 10% level, respectively. Time t and time t-1 are denoted as (t) and (t-1), respectively. Small sample F- and t-statistics are reported. Eq. = equation, F-stat = F-statistics. ROW = Rest of the world, Int'l = international.

[A] The model for the United States is estimated without the international wheat price as the inclusion of this variable substantially shortens the sample and worsens the quality of the results.

Table 1B: Three equations system with aggregate consumption

		Uruguay		
Price eq.	Wheat price (t-1)	-0.072		
		(0.292)		
	Supply (t)	0.825 **		
		(0.329)		
	Consumption (t)	0.563		
		(0.610)		
	Export (t)	-0.078		
		(0.073)		
	Time dummy 1993-2008	-7.929 ***		
		(2.244)		
	Constant	18.901 ***		
		(4.539)		
Supply eq.	Supply (t-1)	0.118		
		(0.188)		
	Wheat price (t-1)	-0.032 **		
		(0.013)		
	Oil price (t-1)	0.001 ***		
		(0.000)		
	Real interest rate (t-1)	0.001		
		(0.002)		
	Int'l wheat price (t-1)	1.652 ***		
		(0.523)		
	Constant	-4.929 ***		
		(1.289)		
Consumption eq.	Wheat price (t)	0.180 **		
		(0.090)		
	Per capita income (t)	-0.024		
		(0.017)		
	Time dummy 1993-2008	1.302 **		
		(0.620)		
	Constant	-4.701 ***		
		(1.400)		
Export eq.	Export (t-1)	0.547 **		
		(0.235)		
	Wheat price (t)	-0.875		
		(0.745)		
	Wheat price (t-1)	0.799		
		(0.762)		
	REER (t-1)	-0.230		
		(3.383)		
	Ending stocks ROW(t-1)	-3.411 **		
		(1.413)		
	Constant	-12.235		
		(12.97)		
Goodness of fit statistics		Obs	F-stat	R-sq
Price eq.		20	702***	0.99
Supply eq.		20	20.03***	0.83
Consumption eq.		20	4.63***	0.38
Export eq.		20	4.11***	0.54

See the notes to Table 1A.

Table 2: Three-Stage Least-Squares Estimates for Maize
Table 2A: Five equations system with FSI and feed consumption

		United States	India	China	Thailand
Price eq.	Maize price (t-1)	0.259 *	-0.257	0.540 ***	0.874 ***
		(0.148)	(0.204)	(0.188)	(0.254)
	Supply (t)	-0.270	-0.892 ***	-0.874	-1.069 **
		(0.348)	(0.274)	(1.428)	(0.505)
	FSI (t)	-0.335 ***	0.583 **	0.574	0.115
		(0.122)	(0.283)	(1.553)	(0.124)
	Feed (t)	-2.589 ***	0.277 *	-0.959	-0.050
		(0.648)	(0.140)	(0.93)	(0.142)
	Export (t)	0.184	0.027	0.058	0.032
		(0.160)	(0.017)	(0.125)	(0.046)
	Trend		-0.027 **		
			(0.012)		
	Constant	1.461 **	12.531 ***	1.731	-0.916
		(0.600)	(3.003)	(6.769)	(3.057)
Supply eq.	Supply (t-1)	0.401 ***	0.216	0.989 ***	0.547 ***
		(0.146)	(0.240)	(0.112)	(0.172)
	Maize price (t-1)	-0.066	0.161	0.016	0.725 ***
		(0.052)	(0.241)	(0.017)	(0.234)
	Oil price (t-1)	0.003 **	0.0001 *	-0.0001	0.0000
		(0.001)	(0.0001)	(0.0002)	(0.0000)
	Real interest rate (t-1)	-0.004	-0.010	-0.003	-0.0004
		(0.004)	(0.011)	(0.003)	(0.006)
	Int'l maize price (t-1)[A]		0.138	0.137	-0.494
			(0.260)	(0.163)	(0.390)
	Trend		0.015 ***		
			(0.004)		
	Constant	0.256	-5.709 ***	-0.402	-6.268 ***
		(0.266)	(2.134)	(0.336)	(1.677)

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FSI eq.	FSI (t-1)	1.095 ***	0.003	0.763 ***	
		(0.070)	(0.336)	(0.092)	
	Maize price (t)	0.049	0.216	0.016	-0.085
		(0.037)	(0.366)	(0.014)	(0.997)
	Per capita income (t)	-0.079	-0.365 ***	-0.107 *	0.401 ***
		(0.184)	(0.127)	(0.064)	(0.135)
	Trend		0.032 *	0.022 ***	
			(0.017)	(0.008)	
	Constant	0.822	-4.156	-0.713 **	-10.422
		(2.110)	(3.301)	(0.277)	(8.335)
Feed eq.	Feed (t-1)	0.156	0.469 **	0.848 ***	1.009 ***
		(0.128)	(0.218)	(0.043)	(0.116)
	Maize price (t)	-0.210 ***	0.338	-0.003	-0.351
		(0.051)	(0.674)	(0.005)	(0.248)
	Cattle heads (t)	0.234 *	1.356	0.056 ***	
		(0.126)	(0.831)	(0.021)	
	Swine heads (t)	0.146		0.005	
		(0.150)		(0.061)	
	Broiler (t)				-0.111
					(0.134)
	Trend		0.046 *		
			(0.025)		
	Constant	1.004 *	-3.261	-0.160 **	2.540
		(0.511)	(7.526)	(0.076)	(2.125)
Export eq.	Export (t-1)	0.412 ***	0.114	0.706 ***	0.811 ***
		(0.149)	(0.207)	(0.194)	(0.116)
	Maize price (t)	0.277	8.871 *	1.313 **	2.544
		(0.223)	(5.252)	(0.621)	(2.747)
	Maize price (t-1)	-0.244	9.376 **	-0.392	
		(0.159)	(3.562)	(0.442)	
	REER (t-1)	-0.732 *	6.845 **	-1.831	0.330
		(0.398)	(2.754)	(1.220)	(1.002)

- Table 2A continued on next page -

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	Ending stocks ROW(t-1)		-0.038			-3.776 **			-1.190			0.506	
			(0.146)			(1.433)			(0.788)			(0.875)	
	Trend					0.550 ***							
						(0.180)							
	Constant		2.064			-229.533 ***			-5.513			-21.792	
			(1.752)			(82.332)			(5.657)			(22.661)	
Goodness of fit statistics		Obs	F-Stat	R-sq	Obs	F-Stat	R-sq	Obs	F-Stat	R-sq	Obs	F-Stat	R-sq
Price eq.		38	38.01***	0.78	22	24.26***	0.90	27	15.82***	0.78	27	2.80**	0.02
Supply eq.		38	12.39***	0.51	22	12.32***	0.81	27	46.76***	0.91	27	3.46***	0.33
FSI eq.		38	1358***	0.99	22	6.66***	0.58	27	88.91***	0.93	27	4.48**	0.31
Feed eq.		38	7.50***	0.39	22	71.07***	0.94	27	3465***	0.99	27	127.80***	0.94
Export eq.		38	8.98***	0.47	22	12.23***	0.82	27	4.26***	0.32	27	14.35***	0.70

See the notes to Table 1.

[A] The model for the United States is estimated without the international maize price as the inclusion of this variable substantially shortens the sample and worsens the quality of the results.

Table 2B: Three equations system with aggregate consumption

		Ecuador	Australia
Price eq.	Maize price (t-1)	1.003 ***	0.647 ***
		(0.026)	(0.124)
	Supply (t)	2.522	0.433
		(2.129)	(0.415)
	Consumption (t)	-1.973	-0.633 **
		(1.867)	(0.315)
	Export (t)	-0.274 *	-0.045
		(0.155)	(0.041)
	Time dummy[A]	-10.218 ***	
		(0.368)	
	Constant	-0.484	0.722
		(0.978)	(0.937)
Supply eq.	Supply (t-1)	0.719 ***	-0.369 **
		(0.152)	(0.177)
	Maize price (t-1)	-0.021 *	-0.024
		(0.010)	(0.267)
	Oil price (t-1)	-0.004 *	0.004 **
		(0.002)	(0.002)
	Real interest rate (t-1)	0.003	0.005
		(0.002)	(0.012)
	Int'l maize price (t-1)	0.508	0.348
		(0.405)	(0.412)
	Trend		0.025 **
			(0.009)
	Constant	-1.522	-6.986 ***
		(0.952)	(1.979)
Consumption eq.	Consumption (t-1)	0.669 ***	-0.109
		(0.189)	(0.159)
	Maize price (t)	0.004	-0.010
		(0.009)	(0.313)
	Per capita income (t)	0.060 **	-0.523 **
		(0.028)	(0.218)
	Trend		0.046 ***
			(0.012)
	Constant	-1.456 *	-0.327
		(0.742)	(3.447)
Export eq.	Export (t-1)	0.601 ***	0.478 **
		(0.148)	(0.228)
	Maize price (t)		3.930 *
			(2.266)
	Maize price (t-1)	0.075 **	-2.572
		(0.036)	(2.07)
	REER (t-1)	-1.055 *	1.247
		(0.548)	(1.679)
	Ending stocks ROW(t-1)	-1.419 **	1.365 *
		(0.697)	(0.792)
	Constant	-3.666	-6.567
		(3.776)	(7.586)

- Table 2B continued on next page -

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Goodness of fit statistics	Obs	F-Stat	R-sq	Obs	F-Stat	R-sq
Price eq.	21	934***	0.99	25	14.44***	0.67
Supply eq.	21	12.59***	0.78	25	2.42**	0.19
Consumption eq.	21	24.01***	0.77	25	6.45***	0.51
Export eq.	21	7.42***	0.54	25	2.73**	0.31

See the notes to Table 1.

[A] The time dummy for Ecuador refers to the year 2000.

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Table 3: Three-Stage Least-Squares Estimates for Rice – Three equations system with aggregate consumption

		United States	Australia	India	China	Thailand	Egypt
Price eq.	Rice price (t-1)	0.564 ***	0.063	0.716 ***	-0.029	0.651 ***	0.284
		(0.136)	(0.097)	(0.194)	(0.374)	(0.126)	(0.223)
	Supply (t)	-1.395 **	-0.075	-0.786 **	3.118 **	0.350	-4.601 ***
		(0.532)	(0.104)	(0.391)	(1.388)	(0.442)	(1.718)
	Consumption (t)	-0.534 *	-0.542 ***	1.581 ***	-16.271 **	-0.915	3.394 *
		(0.306)	(0.146)	(0.566)	(6.284)	(0.726)	(1.822)
	Export (t)	2.731 ***	0.029	-0.051	-0.126 *	-0.371 **	0.372 *
		(0.770)	(0.053)	(0.031)	(0.068)	(0.185)	(0.209)
	Trend		0.040 ***	0.007			0.060 ***
			(0.011)	(0.006)			(0.015)
	Constant	7.380 ***	1.839 **	4.258 **	-24.018 **	1.082	2.669
		(2.713)	(0.831)	(1.883)	(9.615)	(1.963)	(3.059)
Supply eq.	Supply (t-1)	0.614 ***	0.498 ***	0.408 **	1.052 ***	0.409 ***	0.535 ***
		(0.122)	(0.178)	(0.18)	(0.072)	(0.142)	(0.181)
	Rice price (t-1)	-0.023	-0.113	0.241	0.048	0.049	-0.028
		(0.034)	(0.213)	(0.179)	(0.046)	(0.077)	(0.123)
	Oil price (t-1)	0.002 ***	-0.004 **	0.0000	0.0001	0.0001 **	-0.0002
		(0.001)	(0.002)	(0.0000)	(0.0001)	(0.0000)	(0.0003)
	Real interest	-0.005 **	-0.013	-0.001	0.001	0.002	0.006
	rate (t-1)	(0.002)	(0.013)	(0.009)	(0.002)	(0.002)	(0.003)
	Int'l rice		-0.871 **	0.027	0.179 **		0.206
	price (t-1) [A]		(0.340)	(0.172)	(0.073)		(0.295)
	Trend		-0.014 ***	0.004	0	0.003 *	0.016 **
			(0.005)	(0.003)	(0)	(0.002)	(0.007)
	Drought				-0.042 ***		
	dummy (t)				(0.015)		
	Constant	-1.350 ***	1.465	-3.777 **	-0.616 *	-1.339 *	-2.055 ***
		(0.351)	(1.170)	(1.759)	(0.362)	(0.780)	(0.747)

- Table 3 continued on next page -

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Consumption eq.	Consumption (t-1)	0.443 ***	0.407 ***	0.3	1.032 ***	0.429 ***	0.369 ***
		(0.110)	(0.103)	(0.213)	(0.086)	(0.127)	(0.138)
	Rice price (t)	-0.085 *	-1.142 ***	0.123	0.011	0.036	-0.041
		(0.044)	(0.176)	(0.213)	(0.015)	(0.055)	(0.047)
	Per capita income (t)	0.433 ***	-0.083	0.067	-0.006 ***	-0.053 ***	0.121 ***
		(0.142)	(0.136)	(0.076)	(0.002)	(0.020)	(0.025)
	Trend		0.043 ***	-0.007			
			(0.009)	(0.009)			
	Constant	-6.542 ***	3.695 **	-3.356	0.030	-0.821	-2.723 ***
		(1.908)	(1.85)	(2.124)	(0.134)	(0.656)	(0.575)
Export eq.	Export (t-1)	0.093	0.301 *	0.368 **		0.200	0.278 **
		(0.137)	(0.178)	(0.182)		(0.135)	(0.139)
	Rice price (t)	-0.042	-0.751	-10.701 ***		-2.810 **	-0.869 **
		(0.13)	(1.062)	(3.63)		(1.170)	(0.338)
	Rice price (t-1)	-0.082	-0.345	5.140 **	-1.559 *	1.853 ***	
		(0.095)	(0.562)	(2.153)	(0.916)	(0.687)	
	REER (t-1)	-0.512 **	-0.811	-4.378 ***	0.148	-0.168	0.680 *
		(0.236)	(0.833)	(1.544)	(0.530)	(0.541)	(0.356)
	Ending stocks ROW (t-1)	-0.146	0.680	-1.086 *	1.807	0.021	-0.897 *
		(0.090)	(0.755)	(0.607)	(1.136)	(0.186)	(0.462)
	Trend		-0.038 ***	-0.080		0.019 **	
			(0.016)	(0.071)		(0.009)	
	Constant	-1.681 *	7.488 *	66.668 *	12.987	7.155	-1.953
		(0.988)	(3.995)	(34.052)	(7.944)	(7.640)	(2.474)

-Table 3 continued -

	United States			**Australia**			**India**			**China**			**Thailand**			**Egypt**		
Goodness of fit statistics	Obs	F-Stat	R-sq	Obs	F-Stat	R-sq	Obs	F-Stat	R-sq	Obs	F-Stat	R-sq	Obs	F-Stat	R-sq	Obs	F-Stat	R-sq
Price eq.	38	28.61***	0.59	28	7.44***	0.53	25	9.13***	0.69	28	11.79***	0.62	37	21.20***	0.67	24	11.34***	0.57
Supply eq.	38	36.98***	0.78	28	8.49***	0.70	25	2.09*	0.29	28	77.68***	0.96	37	13.36***	0.65	24	27.46***	0.90
Consumption eq.	38	133.04***	0.92	28	108.50***	0.90	25	2.95**	0.25	28	103***	0.93	37	61.79***	0.85	24	53.11***	0.88
Export eq.	38	2.63**	0.17	28	10.29***	0.73	25	8.52***	0.57	28	2.25*	0.19	37	12.09***	0.40	24	14.72***	0.76

See the notes to Table 1.

[A] The model for the United States and Thailand is estimated without the international rice price as the inclusion of this variable substantially shortens the sample and worsens the quality of the results.

Table 4: Pairwise cross-correlation coefficients between crop variables and aid assistance and biofuels measures

	Price wheat	Price maize	Price rice	FSI wheat	FSI maize	Consumption wheat	Consumption maize	Consumption rice
China								
Biodiesel prod.	0.73**	0.14	0.92***	-0.55	0.95***	-0.26	0.93***	-0.79**
Ethanol prod.	0.90***	-0.05	0.90***	-0.90***	0.94***	-0.73**	0.95***	-0.96***
Biowaste and mass prod.	0.88***	-0.19	0.87***	-0.93***	0.94***	-0.77**	0.96***	-0.93***
Biofuels prod.	0.89***	0.00	0.94***	-0.84***	0.98***	-0.63*	0.98***	-0.95***
Ecuador								
Biodiesel prod.	-	-	-	-	-	-	-	-
Ethanol prod.	0.13	-0.17	-	0.24	0.45	0.16	0.58	0.46
Biowaste and mass prod.	-	-	-	-	-	-	-	-
Biofuels prod.	0.13	-0.17	-	0.24	0.45	0.16	0.58	0.46
India								
Biodiesel prod.	-0.48	-0.74**	-0.50	0.48	0.56	0.46	0.58	0.51
Ethanol prod.	-0.85**	-0.71**	-0.60	0.68*	0.70*	0.66*	0.79**	0.37
Biowaste and mass prod.	-0.68*	-0.82**	-0.96***	0.54	0.55	0.54	0.74**	0.75
Biofuels prod.	-0.84**	-0.74**	-0.61	0.68*	0.71**	0.67*	0.80**	0.40
Australia								
Biodiesel prod.	-0.62	-0.05	0.77**	-0.88***	0.75**	0.56	-0.50	0.00
Ethanol prod.	-0.02	0.27	0.67*	-0.53	0.64*	0.20	-0.38	-0.25
Biowaste and mass prod.	-0.45	0.31	0.86***	-0.97***	0.77**	0.52	-0.39	-0.22
Biofuels prod.	-0.43	0.07	0.78**	-0.80**	0.75**	0.46	-0.50	-0.10
Thailand								
Biodiesel prod.	0.90***	0.93***	0.48	0.54	-	0.29	-0.22	0.42
Ethanol prod.	0.94***	0.90***	0.77**	0.73**	-	0.61	-0.39	0.76**
Biowaste and mass prod.	0.90**	0.91***	0.86**	0.99***	-	0.96***	-0.81**	0.77**
Biofuels prod.	0.96***	0.95***	0.66*	0.67*	-	0.49	-0.33	0.63***
United States								
Biodiesel prod.	0.92***	0.86**	0.78**	0.86**	0.93***	-0.85**	0.88***	0.72*
Ethanol prod.	0.88***	0.76**	0.88***	0.34	0.99***	-0.75**	0.98***	0.78**
Biowaste and mass prod.	0.72**	0.61	0.78**	0.09	0.76**	-0.52	0.67*	0.31
Biofuels prod.	0.87**	0.75*	0.90***	0.68*	0.99***	-0.78**	0.97***	0.76**
Uruguay								
Biodiesel prod.	0.52	0.26	0.51	0.33	-0.14	0.33	0.54	1.00***
Ethanol prod.	-	-	-	-	-	-	-	-
Biowaste and mass prod.	0.55	0.53	0.67*	0.63*	-0.04	0.63*	0.82**	0.63*
Biofuels prod.	0.52	0.26	0.51	0.33	-0.14	0.33	0.54	1.00***

Note: ***, **, and * denote the statistical significance at the 1%, 5%, and 10% level, respectively. Biofuels production involves the production of biodiesel and ethanol and is measured in terms of thousand barrels per day. Biowaste and biomass production is measured in billion kilowatt hours. Dependent on the country, the number of observations varies between 7 and 8 for the biofuels-related variables (2000-2007). There is no information for Egypt.
Source: Energy Information Agency (http://tonto.eia.doe.gov/).