Preliminary and incomplete

The causes of recent food commodity crises

Gal Hochman[1], Scott Kaplan[2], and David Zilberman[3]

Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2013 AAEA & CAES Joint Annual Meeting, Washington, DC, August 4-6, 2013.

[1] Gal Hochman is an associate professor in the Department of Agriculture, Food, and Resource Economics at Rutgers University. Email: hochman@aesop.rutgers.edu
[2] Scott Kaplan is a research assistant in ARE at UC Berkeley. Email: scottkaplan@berkeley.edu
[3] David Zilberman is a professor and holds the Robinson Chair in the department of Agricultural and Resource Economics [ARE] at UC Berkeley. Email: zilber11@berkeley.edu

1. Introduction

Food commodity price inflation has become more frequent in recent years. Some attribute the cause of the inflation to biofuels and biofuel policies (de Gorter 2013), while others argue that it is related to economic growth and the depletion of inventories (Trostle 2008a and 2008b). There is a large body of literature trying to understand food commodity price inflation, and most of this literature uses numerical methods, however the relative importance of the various factors including biofuels is not well understood.

In order to further understand the factors impacting food commodity prices, we develop a statistical model that takes into account previous work. Existing literature provides prior information that is used as a base for more refined statistical estimation of key relations between biofuel and food commodity prices. That is, we resort to Bayesian estimation techniques and estimate a structural empirical model that quantifies the effects of the various factors affecting food commodity prices. We collected historical data on fuel and food prices, GDP per capita, temperature, and regions employing irrigation technologies, among other variables. The data is collected across an array of staple crops and countries.

The statistical results show that the key to commodity-price inflation of maize and soybeans is the depletion of inventories to historically low levels. Our analysis shows that when inventory levels decline and expectations for needed inventory increase, prices tend to spike. Thus, while the direct effect of the corn-ethanol mandate may have caused, on average, 20% of the increase in the price of corn, corn-ethanol made an additional contribution to corn prices by depleting inventories and increasing demand for future inventory imposed by the mandate.

The next section reviews the literature on the different factors affecting food commodity prices, and section 3 presents the multi-market food-commodity model, which we use to derive the empirical equation. Section 4 describes the data used and its sources, while the estimation approach and the assumptions made are described in section 5. The results are summarized in section 6.

2. Literature review

Many studies have been conducted in order to understand the effect of different economic variables on food commodity price trends and general welfare implications. These analyses, which include the use of models to perform simulations with acquired data as well as observation of different variables' effects on food commodities, can be a basis for policy advising. There is a desire to understand each factor's aggregate impact on food commodity prices and total societal welfare. The literature looks at some of the most important factors, including exchange rates, supply and demand, total imports and exports (as well as trade restrictions), energy prices and demand, and most recently, inventory.

Partial equilibrium models, which are essentially the aggregation of supply and demand equations representing economic behavior of agents in one or more markets of interest, have been utilized in predicting the impact of biofuel on the price of food in different regions. Msangi et al. (2007) simulate the impact of biofuel under different scenarios on the price of food in different regions. In one of the scenarios, which focused on rapid global growth in biofuel production under conventional conversion technologies, the price increase for major crops ranges between 30% and 76% by 2020. According to OECD's Aglink model (2008), international prices for vegetable oils would, on average, be about 16% lower than under baseline assumptions, and those for wheat and coarse grains by an estimated 5% and 7%, respectively. Due to the offsetting effect of higher prices for oilseed meals, world oilseed prices would drop by around 3%. In contrast, sugar prices would rise slightly, as Brazilian ethanol producers take advantage of eventually higher ethanol prices and as the slightly lower molasses-based ethanol production in a number of African and Asian countries reduces sugar supply.

Partial models have several limitations, such as lack of acknowledgement of the finiteness of resources such as land, labor, and capital; no explicit budget constraint on households; and no check on conceptual and computation consistency of the model (Hertel 2002). These limitations can be overcome by using a general equilibrium approach. Computable general equilibrium (CGE) modeling is a numerical technique that combines the theoretical framework of Walrasian general equilibrium formalized by Arrow and Debreu (1954) with real world economic data to determine the levels of supply, demand, and price that support equilibrium across a specified set of markets (Wing 2007). These models, which were initially developed to analyze the impact of changes in trade policies and public finance, have subsequently found wide application in the analysis of relationship between energy and the macro economy, the impact of greenhouse gas policies, and most recently in the context of biofuel policies (World Bank, 2008; Burniaux et al. 1991; Hertel 2002). GTAP, LINKAGE, and USAGE are some prominent general equilibrium models that were used to analyze biofuels.

Dixon, Osborne, and Rimmer (2007) use a dynamic CGE model called USAGE to quantify the economy wide effects of partial replacement of crude petroleum with biofuels in the United States. They forecast the impact of the current biofuel policies on the U.S. economy in 2020. Although there is no direct discussion of the impact of these policies on the global price of food, the model predicts a reduction in agricultural exports and an increase in the export prices. Gohin and Moschini (2008) assess the impacts of the European indicative biofuel policy on the EU farm sector with a farm-detailed CGE model and predict positive income effects on farmers in the EU. Birur, Hertel, and Tyner (2010) use the GTAP-E model to study the impact of six drivers of the biofuel boom, namely, the hike in crude oil prices, replacement of methyl tertiary butyl ether (MTBE) by ethanol as a gasoline additive in the United States, and subsidies for ethanol and biodiesel in the United States and EU. However, they modify the GTP-E model to include by-products of biofuel in the GTAP-BIO model. For example, the model with no by-products demonstrates that the price of coarse grains increases sharply in the US, EU, and Brazil by 19.8%, 11.0%, and 9.8%, respectively. The model with by-products presents considerably lower percentage changes of 13.0%, 5.6%, and 7.9% in these countries, respectively. With most other food commodities, prices grow at slightly lower rates when including the byproduct effect than when ignoring it. Timilsina et al. (2012) also utilize a global CGE model to forecast prices for a number of different commodities in 2020 due to land use change as a result of biofuel production. They estimate that while most biofuel energy substitutes decrease in price between 0 and 1%, the highest rise in prices are in food commodities, namely wheat by 2.3%, maize by 3.6%, and sugar by 9.7%. The main drawbacks of a CGE model are the large data requirements and the high degree of complexity.

The food commodity crisis of 2007/2008, which saw large price spikes in several major food commodities, has spawned a new body of literature trying to understand its causes as well as look into the future outlook of food prices. Food crises as well as generally increasing food prices affect developing countries and food insecure households the greatest (Baker 2012). During the price spike between June 2010 and early 2011, average poverty, according to the extreme poverty line of $1.25 per day, rose by approximately 1.1% in low-income countries rose while rising by 0.7% in median income countries (Ivanic, Martin, and Zaman 2012). In many developing countries, the result of this poverty increase was due to a spike in an important commodity. For example, in Bangladesh, there was a 45% increase in the price of rice, in Sri Lanka a 31% increase in the price of wheat, and in Tajikistan a 37% increase in the price of wheat. The poverty rates for these countries increased by 1.49%, 1.29%, and 3.18% respectively (Ivanic, Martin, and Zaman 2012). Dimova et al. (2012) also show that high food prices not only have a tendency to cause people to adjust their food consumption habits, but their income and price elasticities of demand for food as well.

There has also been extensive study on several factors that affect food commodity prices. These factors include population and income growth, biofuel use, crop yields (including weather and investment in agricultural R&D), prices of inputs such as crude oil, trade restrictions, exchange rate, and inventories. Some of these can be broken down categorically into supply and demand factors, however many of them influence both the supply and demand of food commodities.

Global population and income growth are extremely important in understanding food commodity price trends. Development and urbanization as well as income growth lead to increased meat and hence more grain consumption per capita. However, growth is not distributed across the world equally, and recently regions like Asia and Africa have witnessed the most drastic growth patterns. Thus, regional production of grains and livestock is key in food distribution (Meyer and Kalaitzandonakes 2012). Schneider et al. (2011) developed a model to explain the impact of population growth on food demand. In most scenarios, the impact of population growth causes a slight shift in food consumption from animal based products to products of plant origin. The model also accounts for changes in income, and suggests that income change has the highest impact among all exogenous development parameters in increasing animal food share, which is estimated to reach 5% by 2030 (Schneider et al. 2011).

While there is little concrete understanding of the impact of biofuels on food commodity prices after the 2007/2008 crisis, Babcock (2012) found that U.S. ethanol policies modestly increased maize prices from 2006-2009. Hertel and Beckman (2010) show that renewable fuel standards and blend mandates increase global food commodity price volatility by 25%, and the volatility in US coarse grains is 57% higher than in the absence of the RFS and blend mandates. According to Muller, Anderson, and Wallington (2011), biofuel production can explain about 1/3 of the price increase in global cereal and oilseed prices in the next 10 years. Several quantitative studies have been undertaken to estimate the effect of biofuel on the increase in food commodity prices, which are

presented in table 1 below. The highest estimate of biofuel's impact on food price increases is 75%, as predicted by Mitchell (2008).

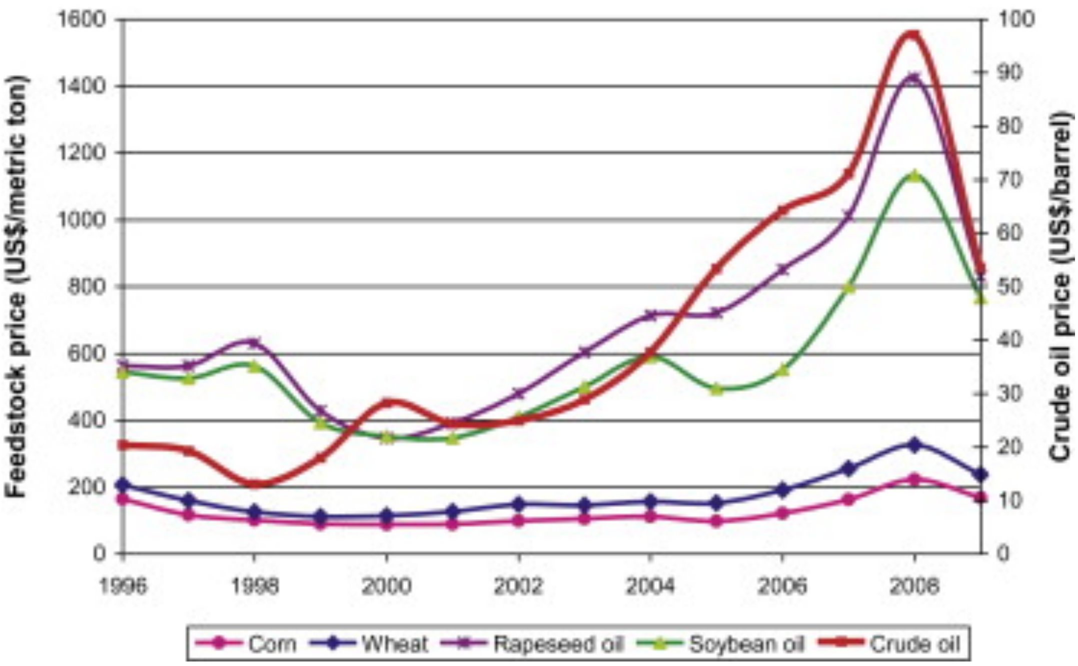
Table 1. Quantitative estimates of impact of biofuel on food commodity prices

Source	Estimate	Commodity	Time Period
Mitchell (2008)	75%	global food index	Jan 2002 to Feb 2008
Rosegrant (2008)	39%	corn	2000 to 2007
	21-22%	rice and wheat	2000 to 2007
OECD-FAO (2008)	42%	coarse grains	2008 to 2017
	34%	vegetable oils	2008 to 2017
	24%	wheat	2008 to 2017
Collins (2008)	25-60%	corn	2006 to 2008
	19-26%	U.S. retail food	2006 to 2008
Glauber (2008)	23-31%	commodities	Apr 2007 to Apr 2008
	10%	global food index	Apr 2007 to Apr 2008
	4-5%	U.S. retail food	Jan to April 2008
Lampe (2006)	35%	corn	Mar 2007 to Mar 2008
	3%	global food index	Mar 2007 to Mar 2008
Rajagopal et al. (2009)	15-28%	global corn price	2007 to 2008
	10-20%	global soy price	2007 to 2008
Hoyos and Medvedev (2009)	6%	global food index	2005 to 2007

Rosegrant (2008) estimates the effect of biofuels using a simulation-based approach. He simulates the market equilibrium under two different scenarios, one without high growth in biofuel and another with high growth in biofuel. For the former, he simulates a scenario in which biofuel grows at a rate which was observed between 1990 and 2000. This is the period before the rapid takeoff in demand for bioethanol. For the latter, he simulates actual demand for food crops as a feedstock for biofuel, from the years 2001 through 2007. Based on these simulations, he estimates that weighted average grain price increased by an additional 30% under the high biofuel scenario, i.e., the actual situation. The increase was highest for maize (39%) and lower for wheat and rice (22% and 21%, respectively). Using a similar approach, Rajagopal et al. (2009) estimate that U.S. ethanol production in 2007 may have been responsible for a 15% to 28% increase in the world price of maize and 10% to 20% increase in the world price of soy.

Crude oil prices also have a direct effect on food commodity prices, and volatility in energy prices great implications for food price spikes and drops. Increases in crude oil prices affects food commodity prices in two main ways: (i) higher food production costs and (ii) increased demand for biofuel as a substitute for oil, putting pressure on food crops used for biofuel. The correlation between monthly logarithmic changes in the IMF's nominal agricultural price index and an average of the WTI and Brent crude oil prices was 0.287 over the 36 months 2006–2008 as against 0.199 over the 36 months 2005–2005 and 0.043 over 2000–2002 (Gilbert 2010). In Figure 1, Ajanovic (2011) portrays the direct association between the volatility in crude oil prices with food commodity price volatility from 1996 to 2009.

Figure 1: The Relationships between Food and Crude Oil Prices from 1996-2009



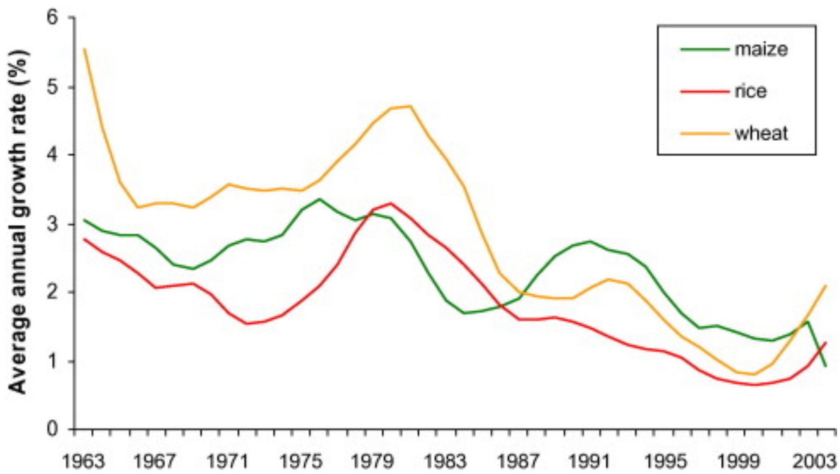
Thompson et al. (2009) also express a positive relationship between crude oil prices and maize prices, noting that a 1%-increase in the crude oil price leads to a 0.31%-increase in the corn price.

While trade restrictions have always been closely linked to international food commodity prices, the 2007/2008 food crisis suggests that trade may have played an extreme part in food commodity price increases. Headey (2011) found that large export volumes in all major crops, with the exception of soybeans, preceded price surges. He finds that *each* major trade shock (export restriction or import surge) in the 2006/2007 period could have increased global prices for major crops 15-27%, and export restrictions in aggregate may have added 61% while import surges in aggregate may have contributed to a 65% increase. Martin and Anderson (2012) also give estimates for the contribution of insulating trade policies to international rice and wheat price increases as 45% and 30%, respectively. There is some inclination that trade restrictions continue to play a large role in food commodity price increases, especially during crises, because the WTO does not regulate agricultural export measures, however this is still an area of continuous study (Martin and Anderson 2012).

Exchange rates continue to have an impact on global food commodity prices as well. There is significant statistical data to show that over-valued (appreciated) exchange rates have a significant negative impact on agricultural growth. Cleaver (2012) shows that of 31 Sub-Saharan African countries, the ones with a depreciated exchange rate saw an average agricultural growth rate of 2.6% while those with an appreciated exchange rate averaged 1.5% (1.1% excluding Botswana). This has significant bearing on food prices as higher growth rates embody many changes that lead to lower food prices. Mitchell (2008) found that between 2002-2007, the depreciating dollar caused food commodity prices to increase by about 20%.

The literature on the impact of inventory on food commodity price increases is sparse, however there are many findings suggesting a low stock to utilization ratio was a major cause of past as well as the recent food commodity crisis of 2007/2008 and is an important factor in understanding prices in general. Piesse and Thirtle (2009) suggest that in 1973, when one of the most significant food crises in the history occurred, the stock to utilization ratio for grains and oilseeds was at an all time low of about 15%. Now, in 2008, it has reached an even lower level of 14% and prices have again risen sharply. In fact, according to the FAO (2008), utilization has exceeded production every year since 1999 with the exception of 2004. Some of this can be attributed to a lack of investment in agricultural R&D. Figure 1 shows the average annual growth rate of major cereals from 1963 until the early 21st century.

Figure 2: World productivity Growth Rates for Major Cereals



Source: World Bank (2008)

3. The food commodity market

The food-commodity market is modeled using a multi-country framework. When constructing this framework, we assume a country's supply for a crop equals amount produced domestically plus imports, while a country's demand for a crop is composed of domestic and foreign food/feed consumed, inventory, and where applicable, demand for biofuels.

When modeling, we use the following notations: The level of a variable is denoted using capital letters, whereas the log of a variable is denoted using lower case letters. Let $\mathrm{s}_{\mathrm{i,j}}$ be log of supply of crop $i \in \mathrm{I}$ in country $\mathrm{j} \in \mathrm{N}$, $\mathrm{d}^{\mathrm{t}}_{\mathrm{fi,j}}$ the log of demand of crop i in country j at time t for food/feed consumption, $d^t_{bi,j}$ the log of demand for crop i in country j at time t for biofuels, and $\iota^t_{i,w}$ the log of global demand for inventory of crop i at time t. Further, let ω_i denote the log of maximum temperature in country j at time t, and let $\tau^t_{i,j,h}$ denote the log of trade policy index $T^t_{i,j,h}$. Let ϕ^t_j denote the exchange rate of currency in country j at time t with respect to the US$ (where $\varphi^t_j = Log(\phi^t_j)$), such that $P^t_{i,j}$ is price in local currency of crop i in country j at time t, $P^t_{i,j,w} = \tau^t_{i,j} P^t_{i,j} / \phi^t_j$ is world price of crop i at time t, and similarly define $P^t_{e,j,w} = P^t_{e,j} / \phi^t_j$ as the price in US$

of energy e in country j at time t. Finally, let y_j^t denote the log of GDP per capita in country i at time t.

The demand and supply equations are log-linear. Country j's supply of crop i equals the sum of harvest and imports of crop i in country j at time t and is modeled as:

$$s_{i,j}^t = \alpha_i^0 + \alpha_i^w\left(\varphi_j^t + p_{i,j,w}^t - \tau_{i,j}^t\right) + \alpha_i^e\left(\varphi_j^t + p_{e,j,w}^t\right) + \alpha_i^\omega \omega_i^t. \tag{1}$$

Because of interest in the importance of biofuels and their effect on food prices, we separate biofuel demand from country j's food/feed demand of crop i. That is, we first define the sum of domestic demand for food/feed consumption, and demand for exports of crop i in region j at time t:

$$\begin{aligned} d_{fi,j}^t = \beta_i^0 + \beta_i^w\left(\varphi_j^t + p_{i,j,w}^t - \tau_{i,j}^t\right) + \beta_i^e\left(\varphi_j^t + p_{e,j,w}^t\right) \\ + \beta_i^{GDP} y_j^t. \end{aligned} \tag{2}$$

Similarly, the derived demand for crop i for biofuel production in region j at time t is modeled as

$$\begin{aligned} d_{fi,j}^t = \gamma_i^0 + \gamma_i^w\left(\varphi_j^t + p_{i,j,w}^t - \tau_{i,j}^t\right) + \gamma_i^e\left(\varphi_j^t + p_{e,j,w}^t\right) \\ + \gamma_i^g\left(\varphi_j^t + p_{g,j,w}^t\right). \end{aligned} \tag{3}$$

In the case where biofuel production is determined through a mandate, the derived crop demand for biofuel is simply a fixed proportion of the mandate. Building on theory developed in de Gorter and Just (2009), we introduced the log of the local price of gasoline $\left(\varphi_j^t + p_{g,j,w}^t\right)$ into the biofuels demand equation.

When modeling crop demand for inventory we follow Hochman et al., (2011), whose work builds on Carter et al. (2009). We construct the national inventory demand assuming the log of inventory is a linear function of price. This equation suggests that large inventory levels correspond to smaller changes in crop prices.

$$\iota_{i,j}^t = \frac{\delta_i^0}{N} + \iota_{i,j}^{t-1} - \delta_i^w p_{i,j,w}^{t-1} + \delta_i^w p_{i,j,w}^t \tag{4}$$

With inventory, the equilibrium price does not need to equate demand with supply. However, it should equate supply, $\sum_{\mathrm{j}} \mathrm{s}_{ij}^{t}$, plus beginning stock, $\iota_{\mathrm{i}}^{\mathrm{t}-1}$, with demand, $\sum_{\mathrm{j}} \mathrm{d}_{ij}^{t} = d_{fi,j}^{t} + d_{bi,j}^{t}$, plus ending stocks, $\iota_{\mathrm{i}}^{\mathrm{t}}$; that is, while using Eqs. (1) to (4) and because markets of individual countries clear, we get the following:

$$p_{i,j,w}^{t} = \frac{\alpha_i^0 - \beta_i^0 - \gamma_i^0 - \frac{\delta_i^0}{N}}{\delta_i^w + \beta_i^w + \gamma_i^w - \alpha_i^w} + \frac{\alpha_i^w + \alpha_i^e - \beta_i^w - \beta_i^e - \gamma_i^w - \gamma_i^e - \gamma_i^g}{\delta_i^w + \beta_i^w + \gamma_i^w - \alpha_i^w}\varphi_j^t$$
$$- \frac{\alpha_i^w - \beta_i^w - \gamma_i^w}{\delta_i^w + \beta_i^w + \gamma_i^w - \alpha_i^w}\tau_{i,j}^t + \frac{\alpha_i^e - \beta_i^e - \gamma_i^e}{\delta_i^w + \beta_i^w + \gamma_i^w - \alpha_i^w}p_{e,j,w}^t$$
$$+ \frac{\alpha_i^\omega}{\delta_i^w + \beta_i^w + \gamma_i^w - \alpha_i^w}\omega_i^t - \frac{\beta_i^{GDP}}{\delta_i^w + \beta_i^w + \gamma_i^w - \alpha_i^w}y_j^t$$
$$- \frac{\gamma_i^g}{\delta_i^w + \beta_i^w + \gamma_i^w - \alpha_i^w}p_{g,j,w}^t + \frac{\delta_i^w}{\delta_i^w + \beta_i^w + \gamma_i^w - \alpha_i^w}p_{i,j,w}^{t-1} \tag{5}$$

We use Eq. (5) to define the empirical equation which we estimate:

$$p_{i,j,w}^{t} = \tag{6}$$

$$\mu_i^0 + \mu_i^\varphi \varphi_j^t + \mu_i^\tau \tau_{i,j}^t + \mu_i^e p_{e,j,w}^t + \mu_i^\omega \omega_i^t + \mu_i^{GDP}\beta_i^{GDP} + \mu_i^g p_{g,j,w}^t + \mu_i^{w,t-1} p_{i,j,w}^{t-1} + \varepsilon_{i,j}$$

where $\varepsilon_{i,j}$ defines the error term. We use the estimated parameters, together with Eq. (6), to compute some of the structural parameters of interest. The empirical analysis estimates Eq. (6), which, together with inventory estimates reported in the literature, can be used to calculate most of the demand and supply parameters. We also compute the empirical variance of these calculated coefficients.

In what follows, let

$$\Omega_i = \begin{pmatrix} \mu_i^0 \\ \mu_i^\varphi \\ \mu_i^\tau \\ \mu_i^e \\ \mu_i^\omega \\ \mu_i^{GDP} \\ \mu_i^g \\ \mu_i^{w,t-1} \end{pmatrix}$$

and define $\Omega = (\Omega_1, \ldots, \Omega_I)$ and $\Theta^{-1} = var(\varepsilon_{i,j})$ the reciprocal of the error precision.

4. The data

We rely on several sources of data to estimate the posterior, as well as compute, quantify, and evaluate the various major factors impacting food commodity prices. We begin with data collected by the U.S. Department of Agriculture on production, supply, and distribution and use it to find production, inventory, and demand in each year in each country for each crop.

A second source of data is FAOSTAT. This data set was used to find the various prices of different crops in different regions in different years in both US$ and LCU (Local Currency Unit) per metric ton, and then to calculate the ratio between the two (exchange rate). This data was expanded using the International Monetary Fund Primary Commodity Prices to document the fuel (petroleum) price index, nonfuel price index, energy price index (total), and the natural gas indices for the EU, Japan, and the US.

Ethanol prices and production for corn in the US and sugar in Brazil was used to find the respective producer prices for corn-based ethanol (E85) and biodiesel in the US ($/gal) and sugar-based anhydrous and hydrous ethanol in Brazil (R$/liter), as well as to document production statistics for corn-based ethanol in the US and Sugarcane-based ethanol in Brazil.

A third source of data we rely on is the World Bank Commodity Price Data. This data was used as an additional source of data to find the various crop world prices, energy world prices (petroleum, coal (Australian), natural gas index, natural gas (US), natural gas (EU), natural gas (Japan)), and annual indices for energy, nonenergy, and fertilizers. We used this source to collect macroeconomic country data including historical population values and real GDP values as well as another source for exchange rates.

Finally, trade restriction data was collected from "Policy responses to rising commodity prices in selected countries"[4] as well as the online database from FAO GIEWS, "Main Food Related Policy Measures", which was used to find whether or not the given countries (found in Asia, Africa, or Latin America/The Caribbean) have a domestic,

[4] ftp://ftp.fao.org/docrep/fao/012/i0854e/i0854e04.pdf

international, or no government crop intervention program. The data was used to document whether the countries have consumer or producer domestic policies, or both. Also, to analyze whether or not the given countries have an input export ban, a complete export ban, an export quota or control, an increase in export taxes, or a reduction/elimination of import taxes, tariffs, or quotas. Data on trade restrictions impacting consumption and production was also collected from Anderson et al. (2012).

5. The approach

Earlier findings suggest that the agricultural commodity price increases were the results of economic growth, biofuel, rise in energy prices, fluctuation of the exchange-rate changes, and weather (see Table 1 – Hochman et al. 2011). The Bayesian approach enables us to use this information when estimating the various parameters and thus refining the estimation results.

Bayesian estimation techniques use prior analysis (in our case, prior studies and experts analysis), to change the prior beliefs and estimate the posterior belief function. It estimates the probabilities of the structure of the model, and uses the estimated posterior distribution function to estimate, calculate, and interpret the model's parameters.

Prior beliefs on relative impact of various factors on food-commodity prices are derived using existing literature (Hochman et al. 2011 and references therein), and are summarized in Table 2. Along with the expansion of biofuels, other demand factors include economic growth, trade restrictions, and fluctuation of the exchange rate. Rapid economic growth (captured by real GDP per capita) results in increased meat production, which is more grain intensive than non-meat products. Fluctuation of the exchange rate impacts local prices, while trade restrictions disrupt the flow of food-commodities among nations. The supply side factors discussed in the analysis include increases in production costs (energy prices and fertilizer costs), and bad weather (the costs of the US drought in 2011 exceeded 10 billion US$ and covered more than 33% of the US, excluding Alaska and Hawaii). While production costs are modeled using the World Bank energy and fertilizer indices, the weather variable simply reports highest recorded temperature in a three-month period.

An important feature of our analysis is explicitly taking into account the adjustments in inventories of a food-commodity in response to demand and/or supply shocks. Although it is conceptually an important component of food-commodity markets, it is not explicitly incorporated into the analysis in most of the empirical studies on food-commodity prices. This feature of model uses previous period food-commodity prices, such that the higher the price in the previous period, *ceteris paribus*, the lower the inventories at the end of the current period (see Eq. (4)).

Another important feature of our approach is the inclusion of gasoline prices (see Eq. (6)). While the energy density of ethanol is 24 MJ/L, that of gasoline is 34.2 MJ/L.[5] The energy content of ethanol is about 70% of that of gasoline, suggesting that the price of ethanol should be 70% of that of gasoline. This link among ethanol and gasoline prices, however, may be violated if the biofuel mandate is binding (de Gorter and Just 2009). The relation between the price of ethanol and that of maize, as well as the price of ethanol and that of gasoline, has been documented extensively in the literature (Serra and Zilberman 2013 and references therein). In the reduced form equation (Eq. (6)) we include the price of gasoline, but only from 2005 onward (the year the US Energy Security Act 2005 was passed and the Renewable Fuel Standard (the biofuel mandate) implemented). This is also the year corn-ethanol demand spiked, because of the phasing-out of MTBE and its replacement with corn-ethanol as an oxygenate blending to gasoline as well as the biofuel mandate.

Table 2: The prior

Factor	Sensitivity (η)	Factor	Sensitivity (η)
Real GDP per capita	0.35	**Gasoline prices**	0.30
Energy price index	0.05	**Max temperature (January to March)**	0.2

[5] Available at http://en.wikipedia.org/wiki/Energy_density.

Fertilizer price index	0.05	**Max temperature (April to June)**	0.2
Exchange rate	0.05	**Max temperature (July to September)**	0.2
Last year's crop price	0.30	**Max temperature (October to December)**	0.2
Trade restriction index	0.10		

Because errors are normally distributed, we make assumptions on the variance such that most observations reported in the literature will fall within the 95% confidence interval (see Table 2).

Table 3: The variance of the prior

Factor	Variance	Factor	Variance
Real GDP per capita	0.2^2	**Gasoline prices**	0.2^2
Energy price index	0.05^2	**Max temperature (January to**	0.2^2

		March)	
Fertilizer price index	0.05^2	**Max temperature (April to June)**	0.2^2
Exchange rate	0.05^2	**Max temperature (July to September)**	0.2^2
Last year's crop price	0.2^2	**Max temperature (October to December)**	0.2^2
Trade restriction index	0.1^2		

Using the prior, we employ Bayesian estimation techniques to estimate the posterior distribution of the parameters and quantify and assess the importance of the various factors.

Throughout the analysis we assume that the conditional distribution of Ω given the precision error Θ is normal and that the marginal distribution of Θ is gamma. Then, (Ω, Θ) has a Normal-Gamma distribution and the priors are natural conjugate priors, which, when combined with the likelihood function, yield posterior distribution functions of the same class of distributions as the priors. Such priors also have the same functional form as the likelihood function.

6. Quantifying the causes of the food commodity price inflation

The spike of the 2007/08 food commodity price inflation marked the depletion of stored grain stocks to historical lows (Peters et al. 2009). The ability to adjust inventories can become a key factor in maintaining price stability and reducing price volatility in the presence of demand or supply shocks (Hochman et al. 2011). The empirical analysis conducted below will assess and evaluate the importance of inventories, while focusing on two key commodities: maize and soybeans.

When deriving the empirical estimates of the various factors, i.e., estimating the point estimates of the parameters of Eq. (6), we proceed in two steps. First, the posterior is calculated by multiplying the likelihood function by the prior and collecting terms. We can then describe the joint posterior distribution. Then, to compute the marginal posterior of Ω_i, we integrate out the error precision coefficient. That is, we compute the posterior mean – i.e., the point estimate of the various parameters of Eq. (6).

6.1. Maize

The point estimates of Eq. (6), while focusing on maize, are depicted in Table 4. The results highlight the importance of inventories and the key role they play in food commodity prices. The importance of inventories is modeled using the lag of the food commodity price, whereby a higher price in period $t-1$ suggests lower inventories in period t – Eq. (4) suggests that period t inventories are negatively correlated with previous period prices, such that, all else being equal, higher $P_{i,j}^{t-1}$ leads to lower current period inventories $\iota_{\mathrm{i}}^{\mathrm{t}}$. This effect is substantial and is also significant at a 5% level. When replacing prices with beginning stocks, the effect becomes even larger.

The analysis also suggests that weather may be key to food commodity prices, modeled as the maximum temperature observed in a given period. Although the parameters are not significant when estimated together, the point estimates fluctuate 17% from April to June and 21% from October through March.

The analysis results in two parameters, whose magnitudes are very different than that suggested in the literature. The first is GDP per capita, which captures economic growth. During the period from 2001-2008, high global economic growth was observed, which leads to increased demand for meat products that, on a per calorie basis, are more grain intensive than nonmeat products. The literature has argued that economic growth is key to the food commodity inflation that peaked in 2007/08 (Trostle 2008a and 2008b; Hochman et al. 2011). However, our point estimate suggests otherwise – it suggests an impact of only 9%, which is not significantly different than 0 at a 5% significance level.

When introducing quantity of corn-ethanol into analysis, its effect is small (not reported in the current paper). However, when biofuels were introduced indirectly into the analysis via gasoline prices, the effect grew significantly and was about 20%. Although this warrants further analysis, these results suggest that biofuel policy and the relation between biofuel prices and petroleum prices is an important factor contributing to maize prices. Further, when estimating the model while incorporating an interaction term between inventories and the corn-ethanol mandate, the effect of biofuels on food-commodity prices is larger – suggesting that the introduction of biofuels has a small impact on food-commodity prices when inventory levels are high, but becomes a key factors leading to food-commodity inflation in the absence of inventories to buffer price changes and reduce price volatility.

The impacts of other factors analyzed in the paper include exchange rate (13%) and energy prices (5%), as well as input costs such as fertilizers (4%). We used both indices reported by the World Bank and the IMF, but there were no substantial differences in the analysis. We also used variations of energy and fuel indices but did not observe differences in the effect of energy and fuel prices on the food-commodity price.

Finally, we incorporated data on trade restrictions (Anderson et al. 2012). The trade restriction index suggests that marginal increments of trade restriction policy result, on average, in food commodity prices increasing by 10%. When using other variations of the trade restriction data some differences are documented.

Table 4: Point estimates: Maize

Variable	Parameter	S.D.
Constant	-5.3996	1.2544
Real GDP per capita	0.0896	0.0818
Exchange rate (USD/LCU)	0.1296	0.0276
Lag of commodity price (inventory demand function variable)	0.5965	0.0425
Trade restrictions	0.0976	0.0267

Energy price index	0.0451	0.0297
US corn ethanol	0.1954	0.1198
Fertilizer price index	0.0385	0.1193
Maximum temperature (January to March)	0.2113	0.1145
Maximum temperature (April to June)	0.1722	0.1165
Maximum temperature (July to September)	0.1951	0.1189
Maximum temperature (October to December)	0.2129	0.1167

6.2. Soybeans

The point estimates of Eq. (6), while focusing on Soybeans, are depicted in Table 4. Similar to maize, inventories are key to soybean prices. The importance of inventories is modeled using lag of the food commodity price, whereby a higher price in period t-1 suggests lower inventories in period t – see Eq. (4). This effect is substantial and is also significant at a 5% level, albeit much lower than that estimated for maize.

Again, although weather is not significant, the point estimate is about 20%. Different from maize, the exchange rate is less important than in maize but energy price index is twice as important to soybeans, i.e, 11%. Both energy and exchange rate are significant at a 5% level. The importance of fertilizers is also larger than in maize (6%).

Table 5: Point estimates: Soybeans

Variable	Parameter	S.D.
Constant	-0.4735	1.4424
Real GDP per capita	0.0164	0.0725
Exchange rate (USD/LCU)	0.0051	0.0374
Lag of commodity price (inventory demand function variable)	0.2167	0.0642
Energy price index	0.1101	0.0441
Fertilizer price index	0.0652	0.0466
Maximum temperature (January to March)	0.2054	0.1607
Maximum temperature (April to June)	0.2407	0.1871
Maximum temperature (July to September)	0.25	0.1876
Maximum temperature (October to December)	0.2633	0.175

7. Conclusion

This paper uses a Bayesian estimation approach to use estimates from prior literature, refine those estimates using country-level data from 1991 to 2010, and shed new light on food-commodity inflation. The statistical results show that the key to commodity-price inflation of maize and soybeans is the depletion of inventories to historically low levels. Our analysis shows that when inventory levels decline and expectations for needed inventory increase, prices tend to spike. Thus, while the direct effect of the corn-ethanol mandate may have caused, on average, 20% of the increase in the price of corn, corn-ethanol made an additional contribution to corn prices by depleting inventories to historical lows and increasing demand for future inventory imposed by the mandate resulting in even higher food-commodity prices.

8. References

1. Ajanovic, A. 2011. "Biofuels versus food production: Does biofuels production increase food prices?." *Energy* 36.4: 2070-2076.
2. Anderson, K. and S. Nelgen. 2012. "Updated national and global agricultural trade and welfare reduction indexes, 1955 to 2010", spreadsheet at www.worldbank.org/agdistortions, World Bank, Washington DC, March.
3. Arrow, K.J. and G. Debreu. 1954. Existence of an equilibrium for a competitive economy. *Econometrica: Journal of the Econometric Society* 22(3): 265–290.
4. Babcock, B.A. 2012. "The impact of US biofuel policies on agricultural price levels and volatility." *China Agricultural Economic Review* 4(4): 407-426.
5. Baker, J.L. 2012. "Impacts of financial, food and fuel crisis on the urban poor." *The World Bank*.
6. Birur, D.K., T.W. Hertel, and W.E. Tyner. 2007. Impact of biofuel production on world agricultural markets: a computable general equilibrium analysis. In the Annual Conference on Global Equilibrium Analysis, Purdue University.
7. Burniaux, J.M., J.P. Martin, G. Nicoletti, and J.O. Martins. 1991. GREEN–A multi-region dynamic general equilibrium model for quantifying the costs of curbing co2 emissions: a technical manual. *OECD Economics Department Working Papers*.
8. Carter, C., G. Rausser, and A. Smith. Causes of the food price boom. Agricultural and Resource Economics Update, 12(2), 2008.
9. Cleaver, K. 2012. "The impact of price and exchange rate policies on agriculture in sub-Saharan Africa." *Institute for Development Studies.*
10. Collins, K. 2008. The role of biofuels and other factors in increasing farm and food prices: a review of recent developments with a focus on feed grain markets and market prospects. Written as supporting material for a review conducted by Kraft Foods Global, Inc. of the current situation in farm and food markets.
11. De Gorter, H., and D. Just. 2009. “The Economics of a Blend Mandate for Biofuels.” *American Journal of Agriculture Economics* 95(3): 738-750.
12. Dimova, R., I. Gang, M. Gbakou, and D. Hoffman. 2011. "The impact of food and economic crises on diet and nutrition." *Brooks World Poverty Institute Working Paper* 175.
13. Dixon, P.B., S. Osborne, and M.T. Rimmer. 2007. The economy-wide effects in the United States of replacing crude petroleum with biomass. *Energy & Environment*, 18(6): 709–722.
14. FAO. 2008. Global information and early warning system GVIEWS, crop prospects and food situation, February, July, and October. *Global Cereal Supply and Demand Brief.*

15. Glauber, J. 2008. Testimony of USDA Chief Economist Joseph Glauber before the Joint Economic committee of Congress.
16. Gohin, A. and G. Moschini. 2008. Impacts of the European biofuel policy on the farm sector: a general equilibrium assessment. *Review of Agricultural Economics*, 30(4): 623–641.
17. Hertel, T.W. 2002. Applied general equilibrium analysis of agricultural and resource policies. *Handbooks in Economics*, 18(2A): 1373–1420.
18. Hertel, T.W., J. Beckman. 2010. Commodity price volatility in the biofuel era: an examination of the linkage between energy and agricultural markets. *GTAP Working Paper No. 60*; https://www.gtap.agecon.purdue.edu/resources/download/4963.pdf.
19. De Hoyos, R.E. and D. Medvedev. 2009. "Poverty effects of higher food prices - a global perspective. *World Bank Policy Research Working Paper 4887*.
20. Gilbert, C.L. 2010. "How to understand high food prices." *Journal of Agricultural Economics* 61(2): 398-425.
21. Headey, D. 2011. "Rethinking the global food crisis: The role of trade shocks." *Food Policy* 36(2): 136-146.
22. Hochman, G., D. Rajagopal, G. Timilsina, D. Zilberman. 2011. "The Role of Inventory Adjustments in Quantifying Factors Causing Food Price Inflation." World Bank working paper.
23. Ivanic, M., W. Martin, and H. Zaman. 2012. "Estimating the short-run poverty impacts of the 2010–11 surge in food prices." *World Development*.
24. Lampe, M. 2006. "Agricultural market impacts of future growth in the production of biofuels." Working party on Agricultural Policies and Markets.
25. Martin, W., and K. Anderson. 2012. "Export restrictions and price insulation during commodity price booms." *American Journal of Agricultural Economics* 94(2): 422-427.
26. Meyers, W.H., and N. Kalaitzandonakes. 2012. "World population growth and food supply." *The Role of Biotechnology in a Sustainable Food Supply* 1.
27. Mitchell, D. 2008. "A note on rising food prices." *The World Bank Development Prospects Group*.
28. Msangi, S., T. Sulser, M. Rosegrant, R. Valmonte-Santos, and C. Ringler. 2007. "Global scenarios for biofuels: impacts and implications." *Farm Policy Journal*, 4(2): 1–9.
29. Mueller, S.A., J.E. Anderson, and T.J. Wallington. 2011. "Impact of biofuel production and other supply and demand factors on food price increases in 2008." *Biomass and Bioenergy* 35(5): 1623-1632.
30. OECD. 2008. *Biofuel support policies: an economic assessment*. OECD Publishing.

31. OECD-FAO. 2008. OECD/FAO agricultural outlook 2008/2017. Organization for Economic Co-operation and Development, Food and Agriculture Organization of the United Nations, Rome, Italy.
32. Peters, M., S. Langley, and P. Westcott. 2009. *Agricultural commodity price spikes in the 1970s and 1990s: valuable lessons for today. Amber Waves*.
33. Piesse, J., and C. Thirtle. 2009. "Three bubbles and a panic: an explanatory review of recent food commodity price events." *Food Policy* 34(2): 119-129.
34. Rajagopal, D., S. Sexton, G. Hochman, D. Roland-Holst, and D. Zilberman. 2009. "Biofuel and the food versus fuel trade-off." *California Agriculture* (forthcoming).
35. Rosegrant, M.W. 2008. "Biofuels and grain prices: impacts and policy response." Testimony for the US Senate Committee on Homeland Security and Governmental Affairss.
36. Serra, T., and D. Zilberman. 2013. "Biofuel-related price transmission literature: A review." *Energy Economics* 37: 141-151.
37. Schneider, U.A., P. Havlík, E. Schmid, H. Valin, A. Mosnier, M. Obersteiner, H. Böttcher et al. 2011. "Impacts of population growth, economic development, and technical change on global food production and consumption." *Agricultural Systems* 104(2): 204-215.
38. Taheripour, F., T.W. Hertel, W.E. Tyner, J.F. Beckman, and D.K. Birur. 2010. "Biofuels and their by-products: global economic and environmental implications." *Biomass and Bioenergy* 34(3): 278-289.
39. Thompson, W., S. Meyer, P. Westhoff. 2009. "How does petroleum price and corn yield volatility affect ethanol markets with and without an ethanol use mandate?" *Energy Policy* 37(2): 745-749.
40. Timilsina, G.R., J.C. Beghin, D. Van der Mensbrugghe, and S. Mevel. 2012. "The impacts of biofuels targets on land-use change and food supply: a global CGE assessment." *Agricultural Economics* 43(3): 315-332.
41. Trostle, R. 2008a. *Fluctuating food commodity prices a complex issue with no easy answers.* Amber Waves.
42. Trostle, R. 2008b. *Global agricultural supply and demand: factors contributing to the recent increase in food commodity prices.* Outlook Report No. WRS-0801, Economic Research Service, US Department of Agriculture.
43. Wing, I.S. 2007. "Computable general equilibrium models for the analysis of energy and climate policies." Prepared for the *International Handbook of Energy Economics*.
44. The World Bank. 2008. *World Development Report 2008: Agriculture for Development*.