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Publication Date

2014-09-01

DOI

10.1016/j.biombioe.2014.06.012

Peer reviewed

Available online at www.sciencedirect.com

ScienceDirect

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Quantifying the causes of the global food commodity price crisis



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ARTICLE INFO

Article history:

Received 12 May 2011

Received in revised form

28 January 2014

Accepted 16 June 2014

Available online 9 July 2014

Keywords:

Biofuels

Food commodity prices

Food

Fuel

Inventories

ABSTRACT

The food commodity price inflation beginning in 2001 and culminating in the food crisis of 2007/08, and which returned in 2010, reflects a combination of several factors including economic growth, biofuel expansion, exchange rate fluctuations, and energy price inflation. To quantify these influence we developed an empirical model that also included crop inventory adjustments, a factor that is underemphasized in the literature. The study shows that, if inventory effects are not taken into account, the impacts of the various factors on food commodity price inflation would be overestimated. Although our model explains most of the price fluctuation observed in 2001–2011, it is not able to explain all of it. Other factors, such as speculation, trade policy and weather shocks, which are not included in the analysis, might be responsible for the remaining contribution to the food commodity price increase.

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1. Introduction

Food and fuel commodities have been rising during the first decade of the 21st century, reaching record levels by mid-2008 [1–3]. According to the International Monetary Fund (IMF) primary commodity price database, world food commodity prices increased 100% or more from 2001 to 2008 (in 2005 US \$), with prices increasing by almost 300% for rice. These trends have re-emerged during recent years. Although prices declined throughout most of 2009, world food prices

indexes rose to a record in December 2010 because of higher sugar, grain and oilseed prices exceeding levels reached in 2008 [4].

The period between 2001 and 2008 was also the period during which production of biofuels such as ethanol and biodiesel produced from food crops grew several fold. During this time, global ethanol production from maize and sugarcane more than doubled from 30 to 50 hm³, while biodiesel production from edible oilseeds such as soybean, oil palm, and rapeseed expanded six fold from 2 to 12 hm³ [5]. The

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<http://dx.doi.org/10.1016/j.biombioe.2014.06.012>

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increase in biofuel demand in the United States and the European Union (EU) was primarily a response to government mandates and subsidies. This has led to the popular opinion that biofuel policies in the high-income countries are one of the principal causes for the inflation in food commodity prices, because biofuels reduce demand for oil and increase demand for agricultural goods [6]. It is interesting to note that the expansion of biofuels slowed down significantly from 2008 to 2011 with world ethanol production increasing by only 27% [7], but that supply is still tight and inventories low.

This paper aims to identify the main factors affecting food commodity prices, and to also quantify the contributions of these factors. A distinguishing feature of our analysis is taking into account adjustments in inventories of agricultural goods in response to these various factors. Although conceptually an important component of food commodity markets, to the best of our knowledge, it is not explicitly incorporated into existing empirical/computational models.

Inventory levels, and its relation to consumption as captured by stock-to-use, play an important role in food commodity price inflation. The decline in inventories, coupled with the increase in global demand, resulted in a steady but gradual decline in stock-to-use, which declined by more than 50%. Stock-to-use ratio of world grain and oilseed stocks declined from 35% in 1985 to less than 15% in 2005 [8]. Lower stocks, in turn, made it more likely that new sources of demand (e.g., biofuels), or disruptions to supply (e.g., drought), will result in large price changes.

Food commodity prices spiked in 2007/08 and again in 2010/11, because growth of demand for food and feed outpaced supply. For most food commodity crops, the main contributor to the increase demand was economic growth measured with GDP/capita. The increase in biofuels was important factor contributing to the food commodity price spike of 2007/08, which affected the price of some crops more than others. One reason for these differences is that the share

of biofuels in the overall use of a crop varies (Fig. 1). This results in biofuel becoming an important factor for increase in price of rapeseed, but less important for other crops. However, the role of biofuels in the price spike of 2010/11 was much smaller, for any crop, than its role in the 2007/08 price inflation. The depreciation of the U.S. dollar relative to major world currencies has also been a contributing factor to commodity price increases [9,10], as were energy prices [6]. Speculation is another factor that may have affected food commodity prices [11].

On the supply side, some of the major factors included bad weather in key grain-producing regions (especially wheat-growing regions such as the United States and EU) and increase in production costs (due to high energy prices [12]). Other major supply side factors that contributed to the food commodity price inflation, included stagnation of productivity growth due to cumulative underinvestment in agricultural research as well as technology and infrastructure such as irrigation [13,14]. All these supply factors resulted in slow or negative growth in production [1,8,9,15]. Trade policies such as export bans on grains (especially ban of rice exports by several countries in Asia such as Bangladesh, Vietnam, and India [16]) and import tariffs on nongrain biofuels (especially the U.S. import tariffs on cane ethanol from Brazil and on rice in Indonesia [17]) also contributed to the food commodity prices spike of 2007/08, as well as to that of 2010/11.

The rest of the paper is structured as follows. In Section 2, we present a review of the literature on recent increase in food commodity prices and the effect of biofuels on food commodity prices. We introduce the empirical multi-market model of inventory in Section 3. Section 4 describes the results from the numerical simulation. This section demonstrates the importance of understanding the market for inventory to better predict the effect of any large supply or demand shock on food commodity prices. Section 5 concludes and discusses the policy implications from the analysis.

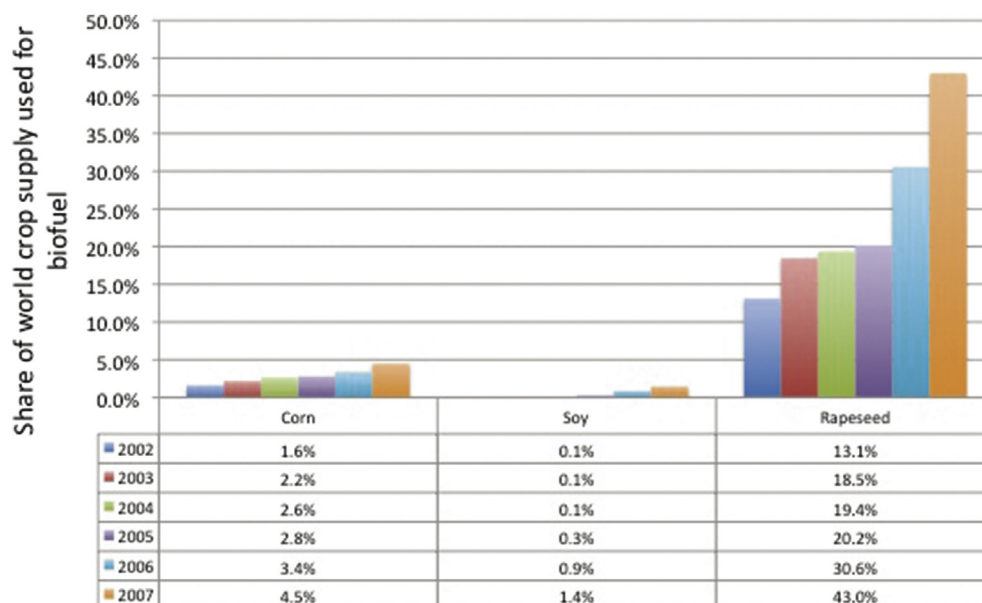


Fig. 1 – Share of corn, soybeans, and rapeseed crops used for biofuel production (2002–2007).

2. Literature review

Abbott, Hurt, and Tyner through a review of several reports on the food crisis conclude that there are several key drivers of food commodity price increases: the depreciation of the dollar, global changes in production such as weather shocks, changes in patterns of food consumption, and the introduction of biofuels [9]. They do not, however, present quantitative estimates of percentage contribution to the total price rise that is attributable to a specific factor such as biofuel consumption. The FAO in its State of Food and Agriculture 2008 Report also states that growing demand for biofuels are only among several factors driving increases in agricultural commodity prices [1]. A USDA report describing the factors leading to the food commodity price rise concludes that the run-up in commodity price reflects a trend of slower growth in production and more rapid growth in demand that led to a tightening of world balances of grains and oilseeds over the last decade [8]. Other reports include [18], which describe the complex interplay of factors underlining the price dynamics of different food crops, as well as [19,20].

Biofuels are considered to be one among several demand-side and supply-side factors responsible for the increase in crop and food commodity prices in recent years [1,10,21–23]. Quantitative estimates of the impact of biofuels on grain prices range from 20% to 60% [24]. The most pessimistic estimate ascribed 70–75% of the price rise between 2002 and 2008 to biofuels [22]. Global estimates of both increase in food commodity prices and the contribution of biofuels to this increase hide variations at the regional level.

Rosegrant estimates the effect of biofuels using a simulation-based approach [10]. He estimates that the weighted average grain price increased by an 30% with the rates of growth of demand for biofuel observed between 2000 and 2007. The increase was highest for maize (39%) and lower for wheat and rice (22% and 21%, respectively). Using a similar approach [25], estimate that U. S. ethanol production in 2007 may have been responsible for a 15%–28% increase in the world price of maize and 10%–20% increase in the world price of soy. The data shows that wheat and rice crops, which have not been utilized to a significant extent as biofuels, are the crops that recorded the highest percentage increase in price in recent years. This clearly suggests that in addition to being region specific, the analyses needs to be crop-specific.

3. The analytical framework

Below we present the empirical multi-market model of inventory, which we use to quantify the various factors.

3.1. The various parts of the multi-market framework

Our analysis decomposes the demand of basic commodities like corn, rice, soybeans, and wheat to three parts. The first is food and feed, which is affected by economic growth and fluctuations in the exchange rate. Strong global growth in average income, particularly in developing countries, increased food and feed demand. As per capita incomes rose, consumers

in developing countries not only increased per capita consumption of staple foods, but also diversified their diets to include more meats, dairy products, and vegetable oils [8]. This, in turn, amplified rising demand for grains and oilseeds used as feed.

Global economic growth increases demand for food, leading to growth in share of meat use. This, in turn, boosts world consumption of feed grains, where most of the growth in global demand for coarse grain trade for feed is in corn [26]. This dynamics has important implications to food commodity prices, in particular to corn and soybean. Although using [27] we can derive feed ratios that relate tonnage of feed needed per ton of animal production, these estimates ignore price-responsive substitution between alternative feeds. Therefore, because of data limitations and the unavailability of separate estimates for the demand elasticity of feed and of food, our numerical analysis does not separate between food and feed.

The second are biofuels, whose use has been modest for several decades, but production rose rapidly in the United States beginning in 2003 and in the EU starting in 2005. Biofuel output increased in response to mounting concerns about rising petroleum prices, the availability of oil supplies, and the environmental impacts of fossil fuels. The growth in worldwide biofuels demand contributed to higher prices for biofuel feedstocks. Biofuel feedstocks like corn, sugarcane, soybeans, and rapeseed now have new uses beyond food and feed. The demand curve now expands, and this expansion is affected by biofuel mandates and subsidies. Biofuels, like economic growth, caused demand to shift up and to the right.

The third source of demand are inventories. The introduction of inventories to our analysis suggests that global consumption does not need to equal production in equilibrium, but it should equal production minus the change in the level of global inventories. That is, the current change in inventories equals the difference between production and consumption. If in the current period consumption outpaced production, then the difference is negative and inventories decline. But if the difference is positive, then production is larger than consumption and inventories increase in the current period. The numerical analysis also assumes global exports equal global imports.

Another factor we consider is the increase in energy prices [6]. To this end, the energy price impact on food commodity prices should be divided into two factors: the allocation of land to biofuel crops (which reduces food and feed availability and increases the aggregate demand for food commodities), and the increase in energy prices (which increases production costs and reduces the supply of food commodities). First-generation biofuels, which are derived primarily from corn and sugarcane, compete with food and feed, resulting in higher demand for agricultural commodities and thus in higher prices. The introduction of biofuels, however, also lowers fuel prices [25]. Yet, the literature fails to recognize that lower fuel prices affect farm-level costs. Introducing energy markets, with all its complexity, to our multi-market framework reduces the impact of biofuels on food commodity prices further.

In sum, we limit our analysis to four factors: biofuel, income, exchange rate, and energy prices. Other factors that

need to be considered, but are outside the scope of this work, are weather, productivity shocks, trade policy, and speculation. We elected to abstract from these shocks due to data and/or model limitations.

We now describe the numerical model used to quantify the effect discussed above, and offer support to our main hypothesis: that successive years of growth in demand outpacing supply led to the gradual depletion of inventory, which reached an historical low in 2008, magnifying the effects that any single factor may have on commodity prices. A more detailed and technical presentation of the numerical model is supplied in the online supplementary material.

3.2. The numerical model

We assume a multi-region framework, where demand for each crop is composed of food/feed, inventory, and where applicable, demand for biofuels. We apply the model for five major crops, namely, corn, rapeseed, rice, soybean, and wheat. With the exception of rice and wheat, all the other crops are currently being used to produce biofuel.

Biofuel from corn, rapeseed, and soybean is jointly produced along with a co-product that is itself a substitute for the raw grain or the oilseed. For instance, in the case of corn, 1 t of corn yields approximately 550 L of ethanol and 321 kg of distiller grains, which is a substitute for corn grain. A fraction of the quantity of original crop used for biofuel is replaced in the form of co-product. Therefore, for these three crops, we compute an effective demand of the particular crop for biofuel, which equals the crop consumption for biofuel minus the quantity of a co-product. In the case of corn, the effective demand of corn is 1.5875 t m³ of ethanol. That is, biofuel production function is of Leontief (fixed-proportion) type.

We divide the world into seven major regions, namely, Argentina, Brazil, China, European Union (EU-27 countries), India, United States, and an aggregate that represents the rest of the world (ROW), and focus on the time period between the year 2001 and the year 2011.

With the exception of the demand for inventory, we assume a linear structure for supply and demand. There are two major approaches for modeling inventories for basic crops like corn, soybeans, wheat, and rice. [28,29] emphasize arbitrage and speculation in generating demand for inventories, while [30] emphasizes inter-temporal production systems. We assume that a demand for inventories exists, and calibrate it. In particular, we assume that the crop demand for inventory is represented as a nonlinear function of price and follow [31]. This model suggests that larger changes in inventory levels would correspond to smaller changes in crop prices.

3.3. Model calibration

We calibrate the crop supply and crop demand functions for each crop, region, and for year 2001, once with demand for inventory and once without. The calibrated demand and supply parameters are used to numerically calculate the effect of each of the different shocks on the observed price in years 2002–2011.

Key parameters in the calibration of these functions are elasticities of supply and demand, i.e., the sensitivity of a

relative change in quantities supplied or demanded to a given relative change in (energy) prices (Table 1). Given the wide range of elasticities reported in the literature and the sensitivity of the simulation to elasticities, for each crop we chose to sample 100 times from within a range of elasticities that are uniformly distributed (for more on sensitivity analysis with numerical models see Refs. [32,33] and references therein). Throughout the paper, we report the mean outcome of 100 simulations. The range of elasticities is shown in Table 1. The elasticity of supply and food and feed demand with respect to energy price is assumed to lie within the range [−0.15,0] and [−0.05,−0.02], respectively. This reflects the assumption that food and feed demand is less responsive than is supply to energy prices.

Note that our specification does not include cross-price elasticities on the supply or the demand-side, which may lead us to underestimate the impact of the different factors on prices. The reason for this is to overcome computational constraints. We chose to investigate the robustness of the results through a sensitivity analysis with respect to own-price, income, and energy elasticities and by employing alternative specifications of the demand function.

Following [31] we estimated the inventory demand parameters using instrumental variable techniques. Because inventory is correlated with the disturbance, whereas harvest is uncorrelated with these disturbances but correlated with inventory (harvest is both exogenous and relevant), we use harvest as our instrumental variable. We tested alternative specifications and also introduced crop-specific dummy variables (Table 2). In all cases, however, we could not reject the hypothesis that the specification chosen is correct.

Given the relevant elasticities for each region, we calibrate the various parameters. The data sources are listed in Appendix A of the online supplementary material, and the mathematical expressions are presented in Appendix B of the online supplementary material.

In Appendix C of the online supplementary material we describe the various shocks mathematically. The shocks eliminate changes in income, biofuel mandate, exchange rates, and energy price between 2001 and a specific year during 2002–2011.

4. Results

We report two different measures of price changes for $i \in \{\text{biofuel, economic growth, energy prices, exchange rate}\}$; namely,

1. The percentage difference between the actual price in a given year and the counter-factual price for the same year ($\Delta P_{t,i}$), and
2. The percentage difference between counter-factual price for a given year and the price in 2001 ($\Delta P_{t-2001,i}$).

The simulations computes $\Delta P_{t,i}$. We then compute $\Delta P_{t-2001,i}$ as follows, where ΔP_t^a denotes the total percentage price change between the year t and year 2001:

$$\Delta P_{t-2001,i} = \frac{\Delta P_{t,i}(1 + \Delta P_t^a)}{\Delta P_t^a}. \quad (1)$$

Table 1 – Range of elasticities used in the baseline scenario.

Commodity	Region	Own-price supply		Own-price demand		Income	
		Elasticity		Elasticity		Elasticity	
		min	max	min	max	min	max
Corn	Argentina	0.65	0.75	−0.4	−0.3	0.35	0.45
	Brazil	0.37	0.47	−0.4	−0.1	0.35	0.45
	China	0.08	0.18	−0.14	−0.6	0.75	1
	EU	0.01	0.13	−0.44	−0.24	0.1	0.2
	India	0.16	0.26	−0.28	−0.22	0.75	1
	U.S.	0.45	0.55	−0.24	−0.1	0.05	0.1
	ROW	0.45	0.55	−0.43	−0.21	0.4	0.6
Soybeans	Argentina	0.27	0.37	−0.3	−0.2	0.35	0.45
	Brazil	0.29	0.39	−0.21	−0.11	0.35	0.45
	China	0.4	0.5	−0.25	−0.15	0.75	1
	EU	0.14	0.24	−0.3	−0.2	0.1	0.2
	India	0.31	0.41	−0.35	−0.25	0.75	1
	U.S.	0.18	0.28	−0.48	−0.31	0.05	0.1
	ROW	0.18	0.28	−0.48	−0.31	0.4	0.6
Rapeseed	Argentina	0.53	0.63	−0.35	−0.03	0.35	0.45
	Brazil	0.53	0.63	−0.35	−0.03	0.35	0.45
	China	0.21	0.31	−0.35	−0.25	0.75	1
	EU	0.23	0.33	−0.13	−0.03	0.1	0.2
	India	0.29	0.39	−0.3	−0.2	0.75	1
	U.S.	0.53	0.63	−0.35	−0.03	0.05	0.1
	ROW	0.53	0.63	−0.35	−0.03	0.4	0.6
Rice	Argentina	0.27	0.37	−0.43	−0.38	0.35	0.45
	Brazil	0.27	0.37	−0.43	−0.38	0.35	0.45
	China	0.27	0.37	−0.71	−0.54	0.75	1
	EU	0.27	0.37	−0.43	−0.38	0.1	0.2
	India	0.27	0.37	−0.43	−0.38	0.75	1
	U.S.	0.27	0.37	−0.87	−0.77	0.05	0.1
	ROW	0.27	0.37	−0.43	−0.38	0.4	0.6
Wheat	Argentina	0.36	0.46	−0.39	−0.28	0.35	0.45
	Brazil	0.38	0.48	−0.38	−0.27	0.35	0.45
	China	0.04	0.14	−0.18	−0.07	0.75	1
	EU	0.07	0.17	−0.33	−0.26	0.1	0.2
	India	0.24	0.34	−0.37	−0.32	0.75	1
	U.S.	0.43	0.53	−0.35	−0.25	0.05	0.1
	ROW	0.43	0.53	−0.35	−0.25	0.4	0.6

Total change in price from year t to year 2001 that is explained by our model equals the sum of $\Delta P_{t-2001,i}$ over all the shocks. The figures depicts the food commodity price reduction attributed to a shock that eliminates one of the factors that caused prices to change after 2001; namely, $\Delta P_{t,i}$. The tables shows the increase in commodity prices from 2001 attributed to one of the factors that caused prices to change after 2001; namely, $\Delta P_{t-2001,i}$. When presenting prices for different crops, we distinguish between two different specifications: one with inventory demand function and another without inventory demand. For each crop, we show the impact of these shocks one at a time.

The observed prices for the different crops are shown in Fig. 2. A clear upward trend, on average, emerges for all crops, albeit some prices increase more than others. Whereas the

price of corn and soybeans increased from 2002 to 2006 by about 63%, the price of wheat increased by more than 74%. Furthermore, while some crops like rice and wheat experienced an upward trend throughout the period, others such as soybeans declined in 2005 and 2006 only to increase by 39% in 2007.

Inventory theory predicts that prices decline when inventory accumulates, and vice versa. The data confirm these predictions, except for soybeans, and show similar trends for stock-to-use ratio. If, however, we drop 2007 (a year where soybean prices spiked), then such a pattern is also observed for soybeans. The increase in demand for feed, coupled with the spike in corn-ethanol consumption during 2006 and 2007, can explain soybean prices in 2007.

Inventory serves as a buffer and affects prices as long as inventory levels are sufficiently large. However, as these levels become small, prices become more volatile and sensitive to the numerous specific factors affecting crop prices. We observe this relation, and less fluctuation is observed if inventory demand is explicitly added to the analysis. The aggregate demand curve becomes much more elastic for large inventory levels, and thus predicts less price volatility.

Table 2 – Inventory demand parameters.

Parameter	Corn	Soybean	Rice	Wheat
α	0.0186	0.0186	0.0186	0.0186
β	−0.8004	−0.5096	−0.5096	−1.4676

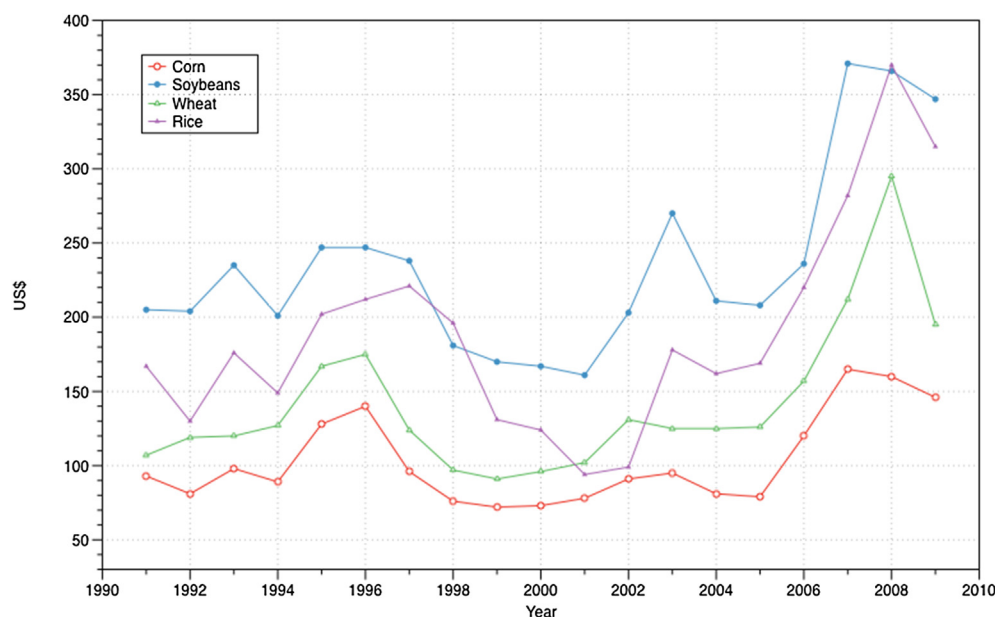


Fig. 2 – Food commodity prices of corn, soybeans, wheat, and rice (1991–2009).

Because we observe inventories and modeling inventory explicitly suggest different magnitude of impact than without a model with inventory, we henceforth emphasize results of simulations that contain a representation of inventory.

4.1. Decomposing the change in crop prices

We now decompose the changes for each crop in turn.

4.1.1. Corn

We find that biofuels contributed 20% to the increase in corn price in 2007 relative to 2001, income shock contributed 30%, exchange rate shocks contributed 16%, and energy shocks contributed at least 11%.

The results of four different shocks, applied one at a time for the period 2002–2007, suggest two dominant factors affect corn prices. The introduction of biofuels and economic growth. Whereas in the absence of an increase in demand for corn, prices would have been 17% lower in 2007, prices would have been 9% lower without the increase in biofuel production. If we ignore the fact that the co-product of corn-ethanol production, namely, distillers grains, is a substitute for corn, then biofuels appropriate a larger quantity of corn that is traditionally consumed as feed and, as a result, become responsible for about 12% of the price increase in 2007. The single largest use of corn is feed grain for animals, which is used for meat and dairy. Furthermore, meat consumption tends to increase with income, resulting in higher demand for corn in emerging economies. As per FAO statistics, in China, which witnessed average growth rate of 8.5% between 1990 and 2003, per capita meat consumption increased 150% from approximately 20 kg per person per year in the year 1985, to approximately 50 kg per person per year by the year 2000. Furthermore, increase in per capita meat consumption

should be expected not only in China but worldwide due to economic growth.

The annual increase in corn prices is large between 2006 and 2007. One explanation for the observed price fluctuation in corn is that consumption of corn for biofuel became significant around 2006 when the federal government began implementing biofuel mandates. Although biofuel subsidies have been in effect for several decades, mandates are the main cause for the recent increase in biofuel production.

However, when analyzing the effect of biofuels on corn prices for the period 2008–2011, we get a significantly lower effect than that computed for the earlier period. By comparing the biofuel effect in the year 2011 with the price of 2008, and contrasting the outcome with that of a comparison between 2011 and 2001, we show that the biofuel effect remains an important factor in 2011 because of its significant impact on inventories in 2006–08. Our model suggests that given demand exceeds harvest, lower beginning stocks lead to higher prices. A biofuel mandate causes inventories to decline in the current period and this has implications for future periods. When comparing the percentage difference between the counterfactual price in 2011 and that of 2008, the biofuel effect is small. However, when comparing the percentage difference between the counterfactual price in 2011 and that of 2001, the biofuel effect becomes large. Biofuels caused inventories to significantly decline during the spike of 2007/08, and this affected corn prices in 2011; the mandate of 2006–08 not only impacts current demand but also affects future supply. Our analysis suggests that from 2001 to 2011, biofuels contributed about 30% to the increase in the price of corn; i.e., biofuels contributes about 20% to the increase of corn prices from 2001 to 2007 and another 10% from 2008 to 2011.

4.1.2. Soybeans

Soybean prices are affected primarily by the increase in demand due to economic growth. The increase in income that led to increased demand, contributed more than 14% to the soybean price spike in 2007. The impact of biofuel is smaller than that for corn and is about 4%. Similar to corn, the single largest use of soybean is feed for livestock and poultry, which has witnessed rapid growth in demand due to economic growth.

Using equation (1), we find that biofuels contributed 7% to the increase in soybean price in 2007 relative to 2001, income shocks contributed 28%, exchange rate shocks contributed 11%, and energy shocks contributed at least 10%.

The annual increase in soybean prices is large between 2006 and 2007. One explanation for the observed price fluctuation in soybeans is that land allocated to corn replaces soybean land, resulting in higher soybean prices (not modeled explicitly because we do not have data on land use). This complements the upward pressure on soybean prices attributed to biodiesel production. However, economic growth results in structural changes to demand in countries like China, where increased demand for feed led to larger demand for soybeans [8] (considerable growth, approximately 20%, between 2000 and 2008 was also observed for pork).

Similar to corn, the effect of biofuels on soybean prices for the period 2008–2011 is very small. But the effect of income remains relatively large at about 30%. The analysis also suggests that fluctuations in exchange rates contributed more than 27% to the increase of the price of soybeans (recall that we do not model trade barriers, but that they do impact the exchange rate). During 2008–2011 the trend of soybean prices followed corn prices with a delay of one year. In addition, the threat of the anti-dumping probe launched toward the end of 2010 by China (which in 2010 was the no. 1 importer of U.S. distillers grains—a co-product of the corn-ethanol distillery industry), resulted in a decline of 15% of distillers grains exports in 2011.

4.1.3. Rice

Because rice and wheat are not utilized for biofuels in any significant quantities, and since rice and wheat do not generally compete with corn, sugarcane and oilseeds [34], we assumed that the prices of rice and wheat are not influenced by biofuels. However, a general equilibrium framework, in contrast to the multi-market framework presented here, includes income effects and may identify indirect linkages between biofuel production and rice and wheat.

Rice prices are affected by the income shock, which contributes 14% to the price increase in 2007. The price dynamics can be explained by the fact that rice is mostly consumed in the fastest growing economies in the world such as China, India, Indonesia, and several countries in South and Southeast Asia. China, India, and Indonesia account for 37%, 23%, and 10% of world rice consumption, respectively.

In response to rising food prices, different countries adopted a range of different short-term measures. A FAO report [35] classifies these measures into three main groups, namely, trade-oriented policies such as reducing import tariffs and export restrictions, consumer-oriented policies such as food subsidies price controls and policies reducing inventory, and thirdly, producer-oriented policies such as input

subsidies. However, world prices escalated as a result of such restrictions [36]. The most severe impact of export restrictions has been on world rice market, which is traditionally thin in trade. In this paper, the impact of trade policy restrictions are indirectly captured through exchange rate shocks, and this magnifies the impact of the exchange rate on rice prices.

Using equation (1), we find that income shock contributed 30% to the increase in rice price in 2007 relative to 2001, exchange rate shocks contributed 13%, and energy shocks contributed 7%. In contrast, income contributed more than 35% to the increase in the price of rice in 2011 relative to 2001, as did the exchange rate shocks.

4.1.4. Wheat

The main contributor to increase in wheat price in our model is the income shock. In 2007 world production of wheat was 607 Mt, making it the third most-produced cereal after maize (784 Mt) and rice (651 Mt). Wheat also supplies much of the world's dietary protein and food supply, with China consuming in 2007 nearly 30% of global wheat consumption. Therefore, the impact of an income shock dominates the other effects.

Using equation (1), we find that income shock contributed 35% to the increase in wheat price in 2007 relative to 2001, exchange rate shocks contributed 20%, and energy shocks contributed at least 9%. In contrast, income and exchange rate shocks contributed more than 35% each to the change of the world price of wheat in 2011 relative to 2001.

4.1.5. Price effect of shocks

We next calculate how much of the total price change the simulation explains, while focusing on the period 2001–2007 and correcting for yield effects reported in the literature [37]. We focus on the period 2001–2007, because we calibrated the demand and supply using 2001 and because this period does not include the global recession of 2008/09. Supply shift due to yield increase reduced upward pressure exerted by the increase in demand. Thus, we use the slope of the supply function, and assume yield growth of 1.5% shifts supply to the right, and compute ΔP_{yield} , i.e., line segment GA in Fig. 3. Then, the amount explained Δ_{AE} by our model is simply

$$\Delta_{\text{AE}} = \frac{\Delta P_t}{\Delta P_t^a + |\Delta P_{\text{yield}}|} \quad (2)$$

where $\Delta P_t = \sum \Delta P_{t,i}$ is the sum of the price change explained by the different shocks ($i \in \{\text{biofuel, economic growth, energy prices, exchange rate}\}$), and recall that ΔP_t^a is the price change observed between period t and 2001, i.e., line segment HC in Fig. 3. Table 3 shows the total explained price increase with respect to 2001.

The amount of the price fluctuation explained by our model is different for different crops, in part because the omitted factors affect some crops more than others. For instance, we did not add trade policy shocks, which affected rice, and we do not have weather shocks, which adversely affected wheat [38].

4.2. Robustness

Key parameters in our analysis and in simulation-based models in general are the elasticities, which are used to

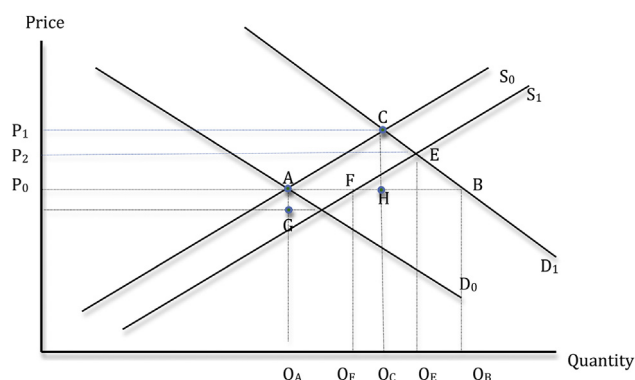


Fig. 3 – The effect of demand and supply factors on food commodity prices.

Table 3 – Total percent price change in 2007 explained by numerical model.

% Explained	With respect to 2001
Corn	70%
Soybean	55%
Rice	47%
Wheat	54%

calibrate the demand and supply curves. To analyze the sensitivity of our results to the models specifications alternative specifications are introduced (see online [Supplementary material](#)). Employing these alternative specifications, we find that the main qualitative conclusions regarding the importance of the different shocks from the baseline scenario hold. All the alternative specifications resulted in similar, although not identical, conclusions and suggested that biofuels, although an important factor, are not the culprit of the food commodity price inflation of 2007/08, and that the biofuel effect of food commodity prices for the period 2008 and 2011 is much smaller.

Although our conclusions are robust to a broad range of assumptions about the price elasticity of supply and demand for crops and parameters of the inventory demand function, another important area of future work is the empirical estimation of these parameters. Correctly estimating the parameters is a challenge, but is a key step to accurately measuring the factors causing the food commodity inflation.

5. Conclusion

Our analysis suggests that, during periods of large inventories (i.e., the first few years of the 21st century), the impact of shocks, such as economic growth, is muted and ignoring inventories does not have a major impact on the model's predictions. However, this conclusion is not true when inventory levels are low. Although inventory declined during most of the investigated period, inventories did serve as a buffer and reduced the impacts of shocks relative to no inventory. From a policy standpoint, the food crisis emphasizes the importance

of both a proactive inventory-management policy and the need for mechanisms that either compensate the poor when prices rise to abnormally high levels or simply mitigate the spike in prices. Such mechanisms may include automatic adjustment of biofuel mandates to situations in food markets, and setting up international institutions that allow poor countries the option of acquiring food at predetermined prices. In the long run, expanding agricultural supply through (1) investment in research and development, (2) introducing regulation that would allow more effective utilization of existing technologies, and (3) investment in outreach and infrastructure that will improve the management of food supply distribution and enhance productivity, can reduce the likelihood of a food price spike.

Acknowledgment

The authors thank the editor and associate editors, as well as anonymous referees, for valuable suggestions and comments that significantly improved the paper. The author also thank the World Bank for financial support (Knowledge for Change (KCP)Trust Fund of the World Bank: RF-P113535-RESE-TF092095), as well as the Energy Bioscience Institute and USDA/NIFA (Multi-State Hatch S1041). Any Remaining errors are the responsibility of the authors.

Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.biombioe.2014.06.012>.

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