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Article

Biofuel and Food-Commodity Prices

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Abstract: The paper summarizes key findings of alternative lines of research on the relationship between food and fuel markets, and identifies gaps between two bodies of literature: one that investigates the relationship between food and fuel prices, and another that investigates the impact of the introduction of biofuels on commodity-food prices. The former body of literature suggests that biofuel prices do not affect food-commodity prices, but the latter suggests it does. We try to explain this gap, and then show that although biofuel was an important contributor to the recent food-price inflation of 2001–2008, its effect on food-commodity prices declined after the recession of 2008/09. We also show that the introduction of cross-price elasticity is important when explaining soybean price, but less so when explaining corn prices.

Keywords: biofuels; commodity-food prices; economic growth; energy prices; exchange rate

1. Introduction

Recent decades have witnessed a growth in demand for energy, which continues to outpace growth in supply of fossil fuels as well as concerns about energy security, fossil fuel price volatility [1], and the environment. This has led to growth in demand for alternative (clean) energy sources, including bioenergy, which is produced using chemical and biological processes to break starch and sugar into carbons. However, the use of plants and especially food crops to produce energy has led to concerns about the overall supply of food, especially to the poor [2]. The ongoing argument asserts that limited land resources and the use of land to produce energy reduce the supply of food. This has spurred a great deal of research on the relationship between food *versus* fuel, and different researchers have taken different views on the matter. While some of the work looks at the relationship between food and fuel prices, other work focuses on the implications of the introduction of biofuels—that is, some have looked at the marginal effect of introducing biofuels whereas others have considered the total effect due to the their introduction [3].

In this paper we survey the two strands of the literature. We follow the explanation offered in reference [3], and argue that in order to understand the impact of biofuels on food prices we should focus on the implications of the introduction of biofuels on food prices. Using global crop data on corn and soybeans, we derive an estimate for the biofuel effect on food commodity prices and investigate the importance of incorporating cross-price elasticity into the analysis.

Section 2 summarizes the two strands of the literature, and concludes that to understand the importance of biofuels we need to look at the total affect, not the marginal effect. Section 3 describes the methodology used to estimate the effect of the introduction of biofuels on corn and soybean prices, while section 4 presents the results. Concluding remarks are presented in Section 5.

2. Literature Review

This literature review focuses on two strands of literature on food and fuel. One strand of literature regarding the implications of the introduction of biofuels uses time-series techniques to investigate the dynamic linkages between food-commodity and fuel prices. As summarized in reference [3], these empirical studies suggest that the relationship between the prices of fuels and food commodities depends on location, the food and fuels considered, the modeling specification, and the time dimension of the data.

Using monthly data from 1990 to 2008, Serra *et al.* [4] used autoregression techniques to identify the relationship between corn, ethanol, gasoline, and oil prices in the United States, finding that the four prices are related in the long run through two cointegration relationships: one representing the equilibrium within the ethanol industry and the other representing the equilibrium in the oil-refining industry. The empirical analysis of Serra *et al.* suggests that in periods of high corn prices, the price of corn becomes the dominant factor in price determination. This complements the results of references [5] and [6], both of whom suggest that when the price of ethanol does not fully adjust to the rise in the price of corn, the corn biorefineries may suffer losses when corn prices are high.

Similar techniques were used by Zhang *et al.*, who investigated the volatility of the wholesale prices of corn, ethanol, soybeans, gasoline, and oil in the United States between March 1989 and December

2007 [7]. These authors concluded that ethanol and oil demands are derived from the demand for vehicle fuel, and that gasoline prices influence both the price of ethanol and oil. They also found a strong link between agricultural commodity and ethanol prices. However, increases in ethanol prices have only short-term rather than long-term effects on agricultural commodity prices.

Other studies employing time-series analysis found that ethanol prices are positively related to both sugar and oil prices, and that price dynamics indicate substitution between oil and ethanol [8]. Zhang *et al.* found long-run relationships between oil and gasoline prices, as well as gasoline and ethanol [9]. The analysis of Kristoufek *et al.* suggests that for quarterly data we observe a correlated dynamic behavior between commodities at the same (or close) geographic location [10]. The authors also found dynamic linkages between food prices as a group and fuel prices as a group with biofuels serving as the link between these markets. McPhail *et al.* developed a joint structural Vector Auto Regression model of the global crude oil, US gasoline, and US ethanol markets, and showed that oil markets respond to ethanol demand shocks differently than to ethanol supply shocks [11].

Overall, this literature suggests that the linkage between ethanol prices and food prices is rather weak, and that the diffusion of shocks between fuel and food prices is very limited. Zilberman *et al.* claim that the weak response of food prices to biofuel prices does not ultimately suggest that the introduction of biofuel has no effect on food prices [3]. They argue that studies employing time-series analysis estimate the coefficient of marginal effect while most of the literature on the impacts of biofuel on food prices assesses the total price effect of diversion of commodities from food to fuel production and that the impact of a change in the price of biofuel on food prices is not clearly connected. They also point out that the impact of the change in the price of biofuels on the change in the price of food commodities can be predicted only when the causes of the change in food prices are specified. Zilberman *et al.* [3] argue that the relationships are likely to be different when assessing different biofuel feedstocks and examining different countries, and that countries should be distinguished according to the extent to which their agriculture is bounded by constraints on natural-resource availability, notably land and water. They conclude that this literature has limited capacity to assess the impacts of biofuel on food prices [3].

The second strand of literature relies on numerical models to assess the impact of the introduction of biofuel on food prices. This strand of the literature includes partial-equilibrium elasticity analysis as seen in reference [12], who show that the introduction of sugarcane ethanol leads to increased demand for sugarcane as well as an increase in supply. An early application of this approach was applied to corn and soybean biofuels [13]. These authors emphasized the uncertainty about the magnitude of both the supply and the demand elasticities. Others, such as in reference [14], used ad-hoc multifactor analysis to analyze the rapid food-price rises between 2002 and 2008 and, through the use of economic logic and results from published studies, reached quantitative conclusions that attributed 70%–75% of the increase in food-commodity prices to biofuels and the consequences of low grain stocks, large land-use shifts, speculative activity, and export bans.

A related body of work analyzes the relationship between the food and fuel markets and the connection between supply and demand in each of them. This body of the literature considers several different policies to minimize the impacts of growth in the biofuel market on the food and feed market. As mentioned in reference [15], different policies better satisfy different criteria, and in order to best satisfy a multitude of criteria, the different policies need to be combined effectively. In the case of food *versus* fuel, a GHG tax is most effective when minimizing the quantity of biofuel produced (and thus increasing the relative share of crops used to produce food) while also maximizing government revenue. The most ineffective policy with relation to the impact on food and feed is an ethanol mandate, as it increases the relative share of crops used to produce biofuel. Yet, according to [16], ethanol mandates only carry heavy influence over corn prices when the margin of ethanol production is low enough to drive production below the levels dictated by the mandate. This can have a large effect when drought or other shocks are prevalent.

The multimarket models also fit among this strand of the literature and include [17] and [18]. Those authors developed a multimarket model to assess the impact of biofuel on fuel and food, emphasizing (i) heterogeneity of land productivity, (ii) multiple crops, and (iii) the relationship between crops and livestock. Chakravorty *et al.* argue that while biofuel standards are important contributors to the rise of food prices, they are not the most dominant and that two-thirds of the increase in food prices will result from increased food demand because of economic growth [17].

In attempting to assess the relative importance of various factors that contributed to the food-price increase in 2007–2008, Hochman *et al.* [19] developed a multimarket analysis that quantifies the impacts of several factors including economic growth, biofuel expansion, and exchange-rate fluctuation, as well as the rise in energy costs on the prices of several agricultural commodities. In addition, their model incorporates inventory levels (based on [20]), a factor that is under-emphasized in the literature. The simulation model [19] shows that when the effects of inventory management are taken into account, the estimated overall impacts of economic growth, increased energy prices, biofuel expansion, and exchange-rate fluctuations on food prices from 2001 to 2007 is roughly 12 percent smaller. To this end, Arseneau *et al.* find that endogenous movement in interest rates implied under general equilibrium enhances the effects of competitive storage on commodity prices [21]. Those authors argue that compared to a model in which the real interest rate is fixed, storage in general equilibrium leads to more persistence in commodity prices and somewhat lower volatility. Hochman *et al.* [19] argue that U.S. biofuel production contributed to 20%–25% of the increase in the price of corn between 2001 and 2007 and 7%–8% of the increase in the price of soybeans during that same period. However, they found that economic growth in developing countries was associated with a 30–38 percent increase in the price of corn, 29%–31% increase in the price of soybeans, 30%–31% increase in the price of rice, and 24%–40% increase in the price of wheat.

Using both the methodology developed in reference [19] and global data collected from public sources, we compute the effects of the various factors (including biofuels) on food commodity prices. We extend [19] and introduce cross-price elasticity, thus modeling the substitutability between corn and soybeans.

3. Methodology

The model follows the one used by Hochman *et al.*, where demand for each crop is composed of food/feed, inventory levels, and demand for biofuels, while expanding that model and introducing cross-price elasticities [19]. The model is applied for two major crops, namely, corn and soybean, which are also used to produce biofuel.

Biofuel from corn and biodiesel from soybeans are each jointly produced with a co-product that provides a substitute for the raw grain or the oilseed used in planting the respective crop. For instance, in the case of corn, 1 bushel (56 pounds) of corn yields approximately 2.75 gallons of ethanol and 18 pounds of distiller grains, which is a substitute for corn grain. A fraction of the quantity of the original crop used in producing biofuel is thus replaced in the form of a co-product. Therefore, for these two crops we compute an effective demand of each particular crop for biofuel production, which equals the crop consumption used in biofuel production minus the quantity of a co-product. In the case of corn, the effective demand is 0.68 (= 1 − 18/56) bushels per 2.75 gallons of ethanol. We assume that biofuel production is represented by a Leontief (fixed-proportion) production function.

We divide the world into seven major regions, namely, Argentina, Brazil, China, the 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.

The crop inventory demand function is represented as a nonlinear function of price and follows [20], where larger changes in inventory levels correspond to smaller changes in crop prices.

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. Given the wide range of elasticities reported in the literature and the sensitivity of the model to different elasticities, we used the mean of a range of elasticities for each crop. The range of elasticities is shown in Table 1. The elasticities of supply and demand with respect to energy price are assumed to be 0.075 and −0.035, respectively. This reflects the assumption that demand is less responsive than supply to energy prices.

Table 1. Mean of elasticities contained in the literature cited in Food and Agricultural Policy Research Institute and United States Department of Agriculture databases.

Commodity	Region	Supply (1)	Demand (2)	Income (3)
Corn	**Argentina**	0.7	−0.35	0.40
	Brazil	0.42	−0.25	0.40
	China	0.13	−0.10	0.88
	EU	0.07	−0.34	0.15
	India	0.21	−0.25	0.88
	U.S.	0.50	−0.17	0.08
	ROW	0.50	−0.32	0.50
Soybeans	**Argentina**	0.32	−0.25	0.40
	Brazil	0.34	−0.16	0.40
	China	0.45	−0.2	0.88
	EU	0.19	−0.25	0.15
	India	0.36	−0.30	0.88
	U.S.	0.23	−0.40	0.08
	ROW	0.23	−0.49	0.50

(1) Own price elasticity of supply; (2) Own price elasticity of demand; (3) Income elasticity of supply.

We also introduced cross-price elasticity, thus modeling soybeans and corn as substitutes. Cross-price supply elasticities of corn with respect to soybeans, and vice versa, are 0.076 and 0.13, respectively [22]. Cross-price demand elasticities of corn with respect to soybeans, and vice versa, are 0.123 and 0.027, respectively [22]. See also [23].

We calibrate the crop supply and crop demand functions for each crop and region during the year 2001. The calibrated supply and demand parameters are used to numerically calculate the effect of each different shock on the observed price in a given year.

We focus on four shocks in this study: Economic growth in each region, biofuel production, energy prices, and exchange rates. To calculate the impact of each of these various factors in their contribution to the change in average yearly price for each commodity, we introduce a shock to the system and calculate the counter-factual world price that would have prevailed. We simulate one shock at a time, where for each type of shock the value of the shocked parameter equals its value in the base year being looked at, *i.e.*, 2001.

The various data sources are shown in Table 2.

Table 2. Sources of data.

Data	Source
Production, consumption and stocks in each region	U.S. Department of Agriculture's Production, Supply and Distribution Data base [24]
Domestic price of grains, sugar and oilseeds	Food and Agriculture Organization of the United Nations (FAO) [25]
World energy price	International Monetary Fund Primary Commodity Prices [26]
Biofuel production and consumption	Renewable Fuels Association [27] and EIA Annual Energy Review, Table 10.3 [28].
Exchange rates	ERS/USDA website [29]
Price and income elasticities of supply and demand for crops	Food and Agricultural Policy Research Institute Elasticity Database [30] and USDA elasticity database [31].

4. The Impact of the Introduction of Biofuels on Food Commodity Prices

The price of corn spiked in 2008. It then rebounded in 2009 and eventually reached US$223 a bushel in 2011; from 2001 to 2011 world corn prices increased by 150%. We find that biofuels contributed about 23% of the increase in the price of corn while economic growth contributed more than 50%. Exchange rate and energy price also contributed, however economic growth overshadows these other factors. This suggests changes in meat consumption, and as a result the demand for feed, are the main drivers of the spike in corn prices during the last decade. When assuming no cross-price elasticity, the effect of biofuels declined only marginally and equaled 22%.

To assess the robustness of our results, we introduced two additional scenarios: an elastic scenario characterized by demand and supply elasticities that are one standard deviation larger than that of our baseline scenario, and an inelastic scenario characterized by demand and supply elasticities that are one standard deviation lower. Under the inelastic scenario, the contribution of both biofuels and income increased by about 7%, to 30% and 56% respectively. But under the elastic scenario, the biofuels contribution to the price of corn declined by a few percent points relative to the baseline scenario.

From 2001 to 2011, the price of soybeans grew by 77%, reaching a price of US$186 in 2011. Growth in income, and thus demand for feed, contributed almost 60% to the increase of the price of soybeans. Here, cross-price elasticity results in a difference of 6% attributed to the impact of biofuels. The impact of biofuels was 20% when the analysis included cross price elasticity but was only 14% without it. Cross price elasticity also made more than a 10% difference in the impact of economic growth and energy prices on the price of soybeans. Similar to corn, when introducing an elastic scenario, the biofuel and the income effects decreased by a few percent points. However, when introducing an elastic scenario, the impact of biofuels declines.

5. Discussion and Concluding Remarks

This paper follows the methodology presented by Hochman *et al.* [19], and focuses on four key factors responsible for the food commodity price inflation, namely, economic growth, biofuel expansion, exchange rate fluctuations, and energy price inflation. It incorporates inventory levels in analyzing the impact of biofuels and other factors on commodity food prices. Hochman *et al.* showed that growth in demand for meat led to the spike in corn and soybean prices in 2007/08 [19]. Our analysis suggests that further growth in income, and thus demand for feed, also resulted in the spike of corn and soybean prices in 2010/11. The introduction of biofuels led to a 25% increase in the price of corn and soybean in 2011 relative to 2001, while economic growth contributed more than 50%. The remaining percent increase in corn and soybean prices was, among other factors, due to the consequences of low inventories, weather, large land-use shifts, speculative activity, and export bans.

Our analysis also suggests that cross-price elasticity may not matter much for corn, but that it is important when assessing the various factors affecting the price of soybean. The introduction of cross-price elasticities among corn and soybeans resulted in the effect of biofuels on soybean prices increasing by 50%; that is, without cross price elasticities, the introduction of biofuels resulted in soybean prices increasing by 14%, but with cross-price elasticities soybean prices increased by 21%, a 50% increase in the effect of biofuels on soybean prices. It also affected the impact of economic growth and changes in demand for feed, as well as the importance of inventories.

Further analysis is warranted for us to fully understand the importance of cross-price elasticity and the implication of ignoring it in future numerical analyses. Continued analysis is also needed in order to assess the robustness of our results with relation to the assumptions made on the elasticities.

Because of the relationship between the food and fuel markets and the connection between supply and demand in each of them, several different policies have been considered in order to minimize the impacts of the growth in one market on the other. Different policies satisfy different criteria, and in the case of food *versus* fuel, a tax is most effective in increasing the relative share of crops used to produce food while an ethanol mandate is considered the least effective, as it increases the relative share of crops used to produce biofuel (see [15]). In sum, this body of literature suggests that due to spillover from other sectors into the food and fuel markets, a well-rounded, combinative policy may be most effective in the long run for stabilizing food and ethanol prices even though one sector is not targeted directly.

From a policy standpoint, the food inflation during the last decade highlights 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 reduce spikes in prices. These mechanisms may automatically adjust biofuel policy to changes in food markets and inventory management policies. However, increasing agricultural supply through investment in research and development, introducing regulation that allows for more effective utilization of existing technologies, and investment in outreach and infrastructure that enhances productivity reduces the likelihood of a food price spike.

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