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# The Post 2008 Food Before Fuel Crisis: Theory, Literature, and Policies

Cheng Qiu, Gregory Colson and Michael Wetzstein  
*Department of Agricultural and Applied Economics, University of Georgia*  
 USA

## 1. Introduction

As early as 1983, research began to appear indicating the potential for biofuel production to emerge as a disruptive force in US and world food sectors (Barnard, 1983). Of particular concern in early and present research is that increased use of agricultural outputs for energy, as opposed to foodstuffs, could ultimately lead to a net welfare loss where the benefits of biofuels are outweighed by the negative consequences linked to reduced food availability. This dilemma emerges due to the direct competition between biofuel and food production for the same renewable and nonrenewable resources critical for their sustainability (Rajagopal and Zilberman, 2007 and von Urff, 2007). In 2007-2008, global food prices experienced a significant upward spike resulting in political and economic instability, conflict, and hardships in both the developed and developing world. Figure 1 illustrates the United Nations FAO monthly food price index and the cereals price index since 2000. As indicated in the figure, in 2006 food prices started to rise with the most rapid increases occurring in 2007 through the middle of 2008 when an equally rapid price decline occurred. Relative to the general food price index, the increase in cereal prices was more pronounced.

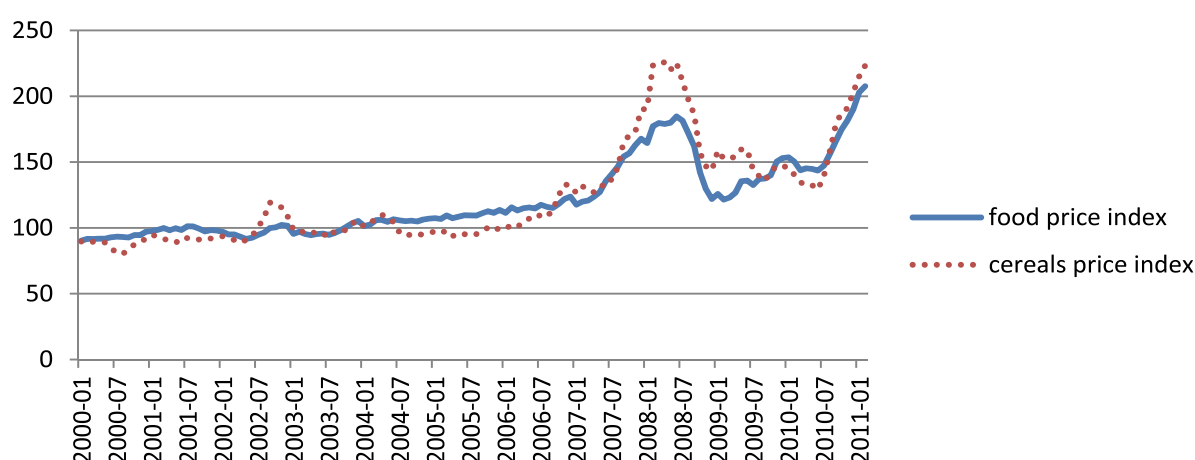


Fig. 1. UN FAO Monthly Food Price Index (2002-2004=100),  
<http://www.fao.org/worldfoodsituation/wfs-home/foodpricesindex/en/>

The effects of the spike in food prices were particularly acute in parts of Africa, Asia, the Middle East, and South America where significant portions of household budgets are spent

on food (e.g., 50-70% of typical household budgets in Africa are spent on food, Diao et al., 2008). This resulted in not only a worsening of poverty statistics, but also led to aggressive national protectionist food policies, civil unrest, malnutrition, and deaths. In general, populations most vulnerable to significant rises in food prices are those in countries that suffer food deficits and import oil. These two features are directly correlated with a country’s income status, with the majority of the 82 low-income countries having food deficits and being net oil importers (Senauer, 2008; Runge and Senauer, 2007). With assumption of biofuels produced mainly with corn, causing food price inflation, countries where corn is the major food grain will generally experience larger increases in food costs, while countries with rice as the major food will experience less of an increase. Countries where wheat and/or sorghum are the major food grains fall in between. Consequently, the highest percentage cost increases are observed in Sub-Saharan Africa and Latin America and the lowest percentage cost increases are in Southeast Asia (Elobeid and Hart, 2007).

A widely considered view both in policy circles and the domain of public perception is that the dominant underlying driver of the 2007-2008 price spike was increased use of crops for the production of biofuels (Diao et al., 2008; Abbott et. al, 2008). This shift from fossil fuels to biofuels, which has in large part been fostered through national agriculture and energy policies motivated by increased oil price volatility, energy security ambitions, and environmental concerns, is particularly prominent among many Kyoto Protocol signatory countries (Balcombe and Rapsomanikis, 2008). In effect, the emergence of a significant biofuel market has given producers a choice of supplying food or fuel depending on their relative net returns (Brown, 1980; Zhang et. al, 2010). However, the rapidly growing market for biofuels has given rise to the perception that rapid biofuel expansion generates upward pressure on global food prices, exacerbating global hunger problems (Runge and Senauer, 2007). Figure 2 illustrates this rapid biofuel growth for U.S. ethanol production. Some

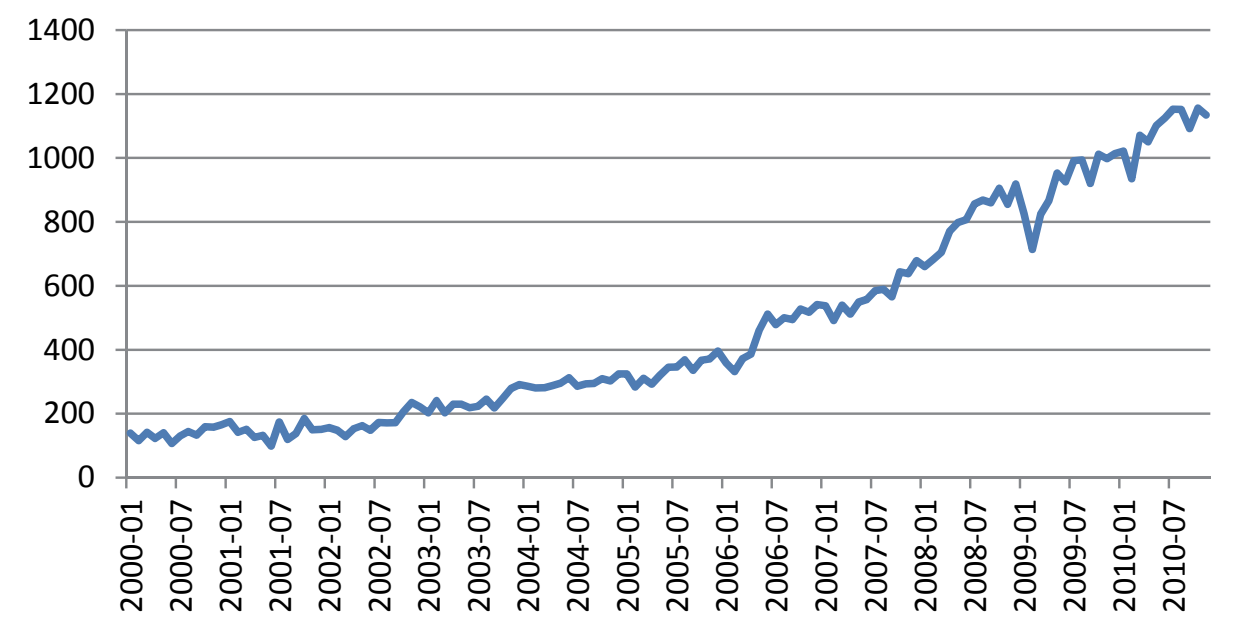


Fig. 2. U.S. Total Production of Fuel Ethanol (Million Gallons), <http://www.eia.gov/totalenergy/monthly.cfm#renewable>

estimates have even placed the number of malnourished people globally at 1.2 billion, twice the number without any effects on the food supply due to biofuels (Runge and Senauer, 2007). These concerns have given rise in some policy circles of calls for agricultural and energy policies be reprioritized where food takes precedence before fuel (in short food before fuel).

In contrast to this perception, evidence is provided countering the hypothesis that the 2007-2008 food price spike was the result of shifts in crop usage from food to fuel. Instead evidence is presented supporting the hypothesis that the food crisis was the result of a shift in global policies toward relying primarily on markets to provide adequate agricultural commodities in periods of supply shortfalls and demand increases. Given this evidence and underlying supporting economic theory, policies capable of averting future food crises are presented.

This hypothesis addressing the root of the global food crisis is first framed in the context of the historical underpinnings of the 2007-2008 food price spike and the prevailing economic view at that time supporting policies contributing to the spike. The literature warning of the potential for biofuels to disrupt global agricultural commodity prices is then presented in an economic theory context. One of the key predictions of economic theory is that global competitive agricultural commodities markets will respond to commodity price shocks, restoring prices to their long-run trends. However, due to inherent frictions in the market, costly or irreversible decisions, and uncertainty, there is a lag time in such response, thus yielding potential short-run volatility in food prices.

## 2. Theory

Surges and downturns of ethanol and food prices are not isolated incidents, but economic consequences (Gohin and Chantretn, 2010; Von Braun et al., 2008; Mcphail and Babcock, 2008; Chen et al., 2010; Balcombe and Rapsomanikis, 2008). Kappel et al. (2010) argue that fundamental market forces of demand and supply were the main drivers of the 2007-2008 food price spike. In a supply and demand model, economic theory suggests agriculture will respond to a commodity price increase from a biofuel or other demand shock. As illustrated in Figure 3, a demand shock will shift the demand curve outward from  $Q_D$  to  $Q_D'$ . This results in a short-run increase in the agricultural commodity price, from  $p_e$  to  $p_e'$ , leading to existing firms earning short-run pure profits (total revenue above total costs). The magnitude of this increase in price depends on how responsive supply, in the short run, is to the demand shift (represented as an increase in supply from  $Q_e$  to  $Q_s$ ). However, in the long-run, existing firms will expand production and new firms will enter yielding a further increase in supply. Assuming no cost adjustments, this increase in supply will restore the market price to the long-run equilibrium price  $p_e$ . Furthermore, given the relative unresponsiveness of demand and supply for staple food commodities, small shifts in demand leads to a significant movement in prices.

Abbott, et al. (2008) identified three major agricultural demand shifters causing the 2007-2008 food price spike: increased food demand, low value of the dollar, and a new linkage of energy and agricultural markets. These demand shifters drove up the prices of agricultural commodities in 2007 and 2008. In 2009, high market prices spurred increased crop-production shifting supply outward and the global economic downturn at the end of 2008, sharply decreased demand and as a result led to lower agricultural commodity prices. Figure 4 illustrates this agricultural commodity price volatility for the U.S. corn market.

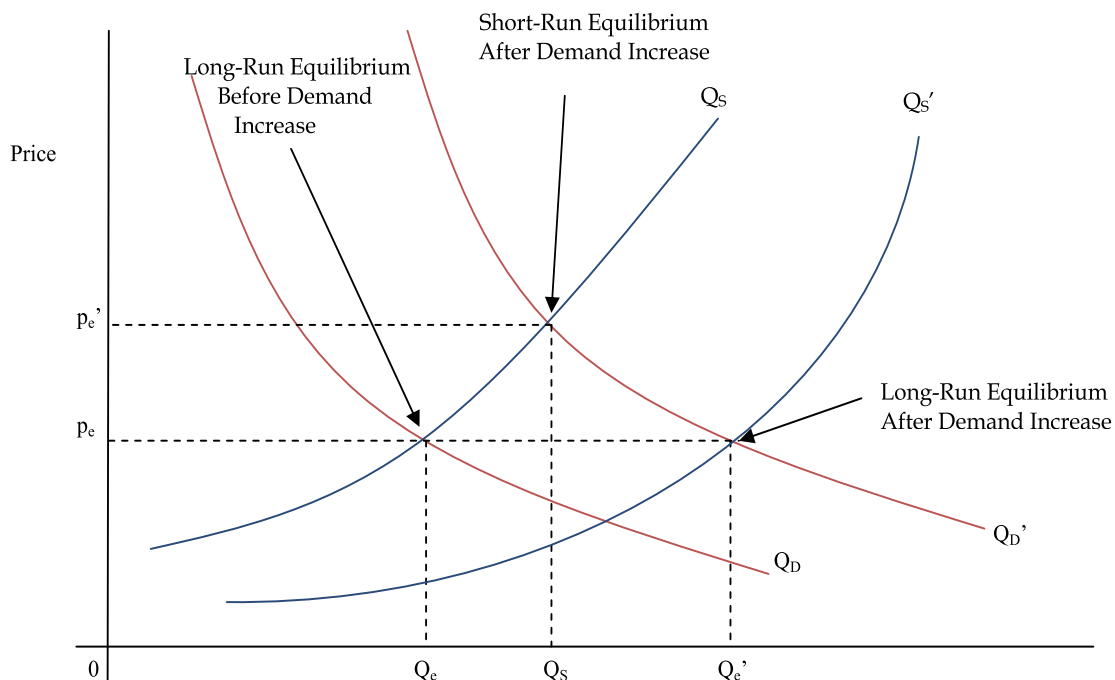


Fig. 3. Supply and Demand Short- and Long-run Shifts

U.S. corn prices rapidly increased in 2007-2008, but with a downturn in economic activity (the Great Recession), price precipitously declined. With a resurgence of current economic activity corn prices specifically rebounded along with agricultural prices in general. As indicated in Figure 2, U.S. ethanol production continued to increase during the economic downturn as corn prices fell. The high correlation of biofuel production with agricultural commodity prices during the 2007-2008 food price spike did not continue through the Great Recession.

Generally the responses to the demand shifters are rapid, while supply-utilization adjustments are slower. A shift in demand will elicit an immediate price increase response. While the supply response will take a number of months as agriculture gears up to increased production. With this supply and demand model, the issue is how rapid is this supply response and what is its magnitude. If supply is able to rapidly respond to a demand shift, then there is no food before fuel issue. If not, then there is a cause for concern.

The underlying driver of the 2007-2008 food price spike was the lack of sufficient food stocks to rapidly buffer the price spike and avoid a food before fuel issue. In the late 20th century, many economists and government policymakers assumed open markets were more efficient in stabilizing agricultural commodity prices than maintaining commodity buffer stocks. One example of this view is an article by Jha and Srinivasan (2001) where they conclude that by liberalizing trade, agricultural commodity stocks are no longer required to stabilize prices. With free trade, when a region experiences a shortfall in grains, it can supplement supply by importing from a grain surplus region. This theory works well when there are ample supplies of grains. However, when there is a global grain shortage, without food buffers a food price spike can occur as was experienced in 2007-2008 food price spike. The global agricultural system has historically responded to changing patterns of demand (Prabhu et al., 2008). The issues are: are there sufficient agricultural endowments for a supply response to a demand shift, such as a biofuel shock, and if so, how rapid is this response.

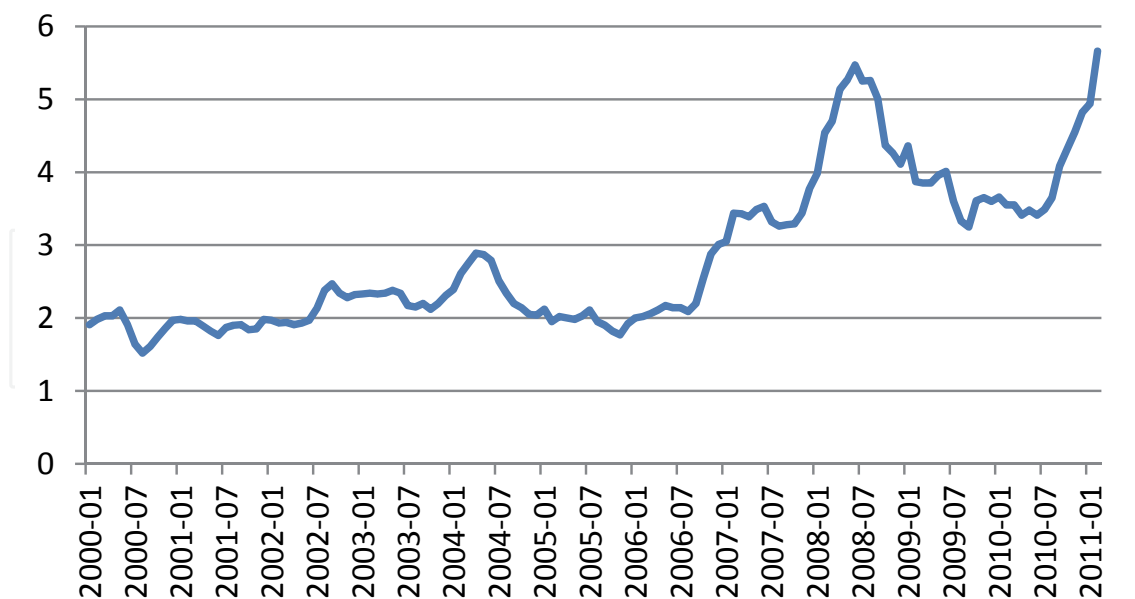


Fig. 4. U.S. Corn Price (dollar per bushel),  
<http://quickstats.nass.usda.gov/#36836568-52F8-393F-9658-05B4E5C1DFB2>

Chen et al. (2010) suggests that increasing derived demand for corn, from biofuel production, has led to acreage declines and associated price increases of other crops (wheat and rice). They see a short-run constraint on agricultural endowments, leading to commodity price increases. However, in the long run, the potential for increasing agricultural production is high. Within the U.S. there is about 35 million acres of idle cropland representing approximately 10% of current cropland in use, along with about 75 million acres of cropland in pasture (Marlow et al., 2004). Africa's abundant arable land and labor offer the potential for it to be a major exporter food (Juma, 2010). Global agriculture in general and U.S. agriculture in particular appear capable of adjusting without major difficulties to even high levels of biofuel production (Webb, 1981; Kerckow, 2007). This ability of agriculture to supply growing demand is supported by Licker et al., 2010 who indicate approximately 50% more corn, 40% more rice, 20% more soybeans, and 60% more wheat could be produced if the top 95% of the crops' harvested areas met their current climatic potential.

In 1979, Vincent et al., (1979) indicated the days of cheap corn are not over. Prices may be more stable as corn production expands to meet ethanol requirements and second generation ethanol, increased buffer stocks, and new technologies emerge (Vincent et al., 1979). This prediction of stable agricultural commodity prices would still hold if supply responses are rapid enough to mitigate demand shocks or global buffer stocks are expanded.

In a game theory context, Su (2010) illustrates how rational expectations will lead to consumers stockpiling commodities when prices are low. This type of rational expectations theory can be directly applied to governments where it would be feasible for them to stockpile agricultural commodities in times of relatively low prices to blunt possible future price spikes. Maintaining a buffer stock of agricultural commodities will provide a rapid supply response to blunt a demand shock and avoid a short-run food before fuel issue. If the world economy recovers from the economic slowdown without food production growing



sufficiently to replenish stocks, food prices and hunger may rise again (Kappel et al., 2010). Currently in 2011 food prices are rising which is one underlying cause of the recent uprisings in North Africa and Middle East.

3. Methodologies

With this underlying theory of global competitive agricultural markets as a foundation, the two main methods, computable general equilibrium (CGE) and time series models, for food before fuel analysis are investigated. The advantages and disadvantages of these models are outlined in Table 1.

<b>Computable General Equilibrium (CGE) Models</b>	
Advantages	Limited data requirements
Disadvantages	Not based on estimated time trends and price volatility Rely on exogenously determined elasticities among food and fuel variables Unless expressly modeled, challenging to distinguish short- and long-run impacts
<b>Time Series Models</b>	
Advantages	Efficient in illustrating the dynamics and measuring the interaction among prices Considers both the short- and long-run impacts
Disadvantages	Spurious results are possible for non-stationary data

Table 1. Methodologies Addressing the Food before Fuel Issue

3.1 Computable general equilibrium models (CGE)

CGE models are widely employed in addressing the food before fuel issues, although with different modeling strategies and focuses (Elobeid and Tokgoz, 2007; Ignaciuk and Dellink, 2006; Arndt et al. 2008; Rosegrant et al., 2008; Tyner and Taheripour, 2008; Yang et al., 2008; Saunders et al., 2009; Gohin and Chantret, 2010; Mcphail and Babcock, 2008; Vincent et al., 1979; Hanson et al., 1993; Saunders et al., 2009). Their advantage is a historical data set containing prices and quantities is not required. Only estimates on the elasticities (responsiveness of one variable to a change in another variable) are required. These estimates could be derived empirically, theoretically, or expert opinion. However, a shortcoming of CGE models is their failure to precisely illustrate the time trends and price volatility, and they are not directly applied to the estimation at a particular point in time (Ignaciuk and Dellink, 2006). An exception is Gohin and Chantret (2010) who model the long-run relationship between food and energy prices and examine an array of energy and agricultural commodities with a wider set of macroeconomic factors. Furthermore, CGE models rely on exogenously determined elasticities among energy and agricultural

commodity variables. This leads to a predetermined relation between food and fuel which makes it challenging to distinguish the short- and long-run impacts. If these elasticities are not supported by theory and empirical evidence, the conclusions they derive concerning the linkages among food, fuel, and other variables including global economic activity are questionable.

### 3.2 Time series models

An alternative avenue of research attempts to determine linkages between food and fuel using time-series models estimated with historical data (Imai et al., 2008; Baek and Koo, 2009; Zhang et al., 2010; Saghaian, 2010; Esmaeili and Shockoohi, 2011). Time-series models, such as autoregressive distributed lag (ADL) models, are widely used for empirical analysis of food before fuel (Bentzen and Engsted, 2001; Dimitropoulos et al., 2005; Hunt et al., 2005; Baek and Koo, 2009; Chen et al., 2010). Such models are efficient techniques for illustrating dynamics and measuring the interaction among prices in a time series context, as well as considering both short- and long-run effects (Chen et al., 2010). For example, with a structural break considered, Baek and Koo (2009) used an ADL model to investigate the short-run and long-run impacts of market factors such as energy prices on U.S. food prices. Chen et al. (2010) built a model where the price of grain is established as a function of its own price and other current and lagged variables such as the prices of oil, soybeans, and wheat.

However, the validity of the ADL approach is questionable on unit roots grounds (Bentzen and Engsted, 2001). ADL is an efficient approach when time-series data are stationary, but for non-stationary data it could yield spurious results unless all the variables are cointegrated. Thus, cointegration tests and vector error correction models (VECM) are suggested as more appropriate techniques to capture possible non-stationary characteristics (Bentzen and Engsted, 2001). These methods are generally augmented with supplementary analysis including Granger casualty tests, pairwise correlation matrix analysis, scree tests, and proportion of variance methods.

## 4. Supply

With energy as a key input into producing agricultural commodities, as prices of energy rise the potential exists for food price inflation. Table 2 outlines the impacts energy has on the supply of agricultural commodities.

### 4.1 Energy input effects on agricultural commodity prices

Conforming to economic theory, prevailing empirical literature indicates that agricultural prices, which are a function of production costs, have a positive relationship with energy prices. The impact these higher energy prices have on agricultural production costs, short-run price volatility, and long-run price trends are investigated in terms of the underlying chapter hypothesis.

Previous spikes in food prices are usually considered as supply driven, and volatility of food prices were considered as a consequence of supply shocks (e.g. weather, pests, and diseases) (Mcphail and Babcock, 2008). Under this scenario, research on how the energy sector influences the agricultural sector considered energy as an agricultural production cost.



<b>Supply</b>	<p>Although fuel is a key input in agricultural production, caution is required in concluding fuel prices directly cause agricultural commodity prices.</p> <p>In the long run, the potential exists for supplying biomass to meet the growing demand for biofuels.</p> <p>Increased biofuel production may impose adverse effect on environmental resources.</p>
<b>Demand</b>	<p>Past research establishing a direct link between food and fuel prices are not consistent with recent trends.</p> <p>The major weakness, in past research, is not differentiating short- and long-run impacts and not considering macroeconomic linkages.</p> <p>Current research trends indicate, in the short run, there is probably some causation between food and fuel, but no long-run relation exists.</p> <p>Macroeconomic activity possibly is the underlying cause of both food and fuel price instability.</p>

Table 2. Supply and Demand Effects on Food and Fuel Markets

This increased energy cost is reflected directly in fuel costs associated with field operations, transportation, and processing and indirectly in increased cost of factors with energy as a major component (e.g., fertilizer and pesticides) (Musser et al., 2006). By substituting other inputs (e.g. reduced tillage technology, improved drying and irrigation systems, and efficient application and timing of fertilizers) the effects of higher energy costs can be mitigated (Musser et al., 2006; Von Braun et al., 2008).

Baffes (2007) indicated that the pass-through of oil price changes to fertilizer and agricultural commodities was high relative to other inputs, thus relatively high oil prices will be passed-through leading to high agricultural commodity prices. However, with lags in cost adjustments, these energy cost-push effects on agricultural commodity prices might not exist in the short-run (Gohin and Chantret, 2010; Von Braun et al., 2008).

The magnitude of these energy cost-push effects are subject to energy use relative to other inputs (Muhammad and Kebede, 2009). For energy-intensive agricultural commodities, with other factors fixed, an increase of energy prices would shift the supply curve of agricultural commodities to the left, which subsequently increases agricultural commodity prices (Chen et al., 2010). However, for labor-intensive agricultural commodities an increase in energy prices might yield insignificant impacts on agricultural commodity prices. Thus, although considered as a key production input for agricultural commodities, care is required in concluding that higher energy prices directly imply higher agricultural commodity prices, especially in the short-run. Gohin and Chantret's (2010) results indicate other factors (biofuels, trade restrictions, speculative demands, climatic events, higher demands, and lower stocks) besides oil prices affecting the cost of agricultural production may better explain agricultural commodity prices.

4.2 Supply potential of bioenergy

Perlack et al. (2005) determined within the U.S. forestland and agricultural land, the two largest potential biomass sources, there exists over 1.3 billion dry tons per year of biomass

potential. This is enough to produce biofuels meeting over one-third of the current demand for transportation fuels. The United States can produce nearly one billion dry tons of biomass annually and still continue to meet food, feed, and export demands. This biomass resource potential can be produced with relatively modest changes in land use. In contrast, Reilly and Paltsev (2007) estimate that large increases in domestic biofuel production would result in the U.S. becoming a net importer of food as opposed to an importer of oil.

Within China, current biofuel development paths could pose significant impacts on China's food supply and trade, as well as the environment. Yang et al. (2009) conducted a study on the land and water requirements for biofuel in China, and found that 3.5-4% of the total corn production was used for ethanol production. They predicted that by 2020, 5%-10% of the cultivated land in China will be used for ethanol-production crops, and that biofuel development will have significant impacts on China's food supply. Food and bioenergy demands can be satisfied at the same time without rising agricultural commodity prices, but significant research and development efforts in agronomy, technology, and markets will be required to ensure efficient, sustainable land use (Rosegrant et al., 2008; Yang et al., 2008).

Natural endowment redistribution is another consequence of the food vs. fuel competition. Increased biofuel production imposes adverse effects on land and water resources (Rosegrant et al., 2008). With the expansion of biofuels, more natural ecosystems are switched to agricultural use, releasing CO<sub>2</sub> originally stored in ecosystems into the atmosphere (Chakravorty et al., 2009; Fargione et al., 2008). Searchinger et al. (2008) estimated that greenhouse gas emission would double over 30 years and last for 167 years due to conversion from natural habitat to cropland caused by increased of biofuel production.

## 5. Demand

Although supply is considered to play a significant role in the long-run relationship between energy and agricultural commodities, the role of demand should not be ignored or underestimated (Gohin and Chantret, 2010). The 2007-2008 food price spike focused research on investigating the demand side. The expanding biofuel market has provided producers a choice of supplying food or fuel depending on their relative net returns. The issue is: can agriculture respond to the growing demand for food and fuel in a time frame sufficiently rapid to avoid commodity price inflation. The literature investigating the food versus fuel demand linkage is mixed. Research has either assumed or empirically derived a direct link between biofuels and food prices, where increased crop demand for biofuel production is limiting its supply for food and thus driving up the food prices. Along with the supply effects on food and fuel markets, Table 2 also lists the demand effects of expanding biofuels on food.

### 5.1 Previous research

Past research concluded, of the factors causing rising food prices (increased biofuel production, weak dollar, and increased food production cost due to higher energy prices), the most important is the large increase in biofuel production in the U.S. and the EU (Martin, 2008; Mitchell, 2008; OECD-FAO, 2007). Without these increases, global wheat and corn stocks would not have declined appreciably and price increases would have been moderate. Since the Energy Act of 2005, a stronger relationship between corn and biofuel (ethanol) has emerged (Muhammad and Kebed, 2009). Although still questionable, biofuel is considered a key transmitter of energy prices to the agricultural prices (Arndt et al., 2008;

Chakravorty et al., 2009; Chen et al., 2011; Elobeid and Hart, 2007; Hochman et al. 2010; Ignaciuk et al., 2006; Ignaciuk and Dellink, 2006; Runge and Senauer, 2007; Lazear, 2008; Mitchell, 2008; Muhammad and Kebed, 2009; Rajagopal, 2009; Sexton et al., 2009; Taheripour and Tyner, 2008; Yahaya, 2006).

Recently, corn price volatility has contributed to the integration between the energy market and the agricultural commodity market (Mcphail and Babcock, 2008). However, this direct linkage between food and fuel prices are not consistent with recent trends and fail to illustrate the connection among food and fuel prices (Chen et al., 2010). The strong positive correlation between U.S. ethanol production and agricultural commodity prices during the 2007-2008 price spike, quickly reversed to a negative correlation in the years following the spike (see Figures 2 and 4). U.S. ethanol production continued to rise with commodity prices falling. A major weakness of these studies is not differentiating between the short- versus long-run food before fuel impacts. Gohin and Chantret (2010) attribute these inconsistencies to the omission in previous studies of macroeconomic linkages. Macroeconomic activity is hypothesized to be the underlying driver of both food and fuel prices.

In sum, Kilian (2009) discusses the importance of differentiating impacts (shocks) between demand and supply, given each of them is associated with different magnitudes, patterns, and persistence. But one of the main shortcomings for most papers is a failure to distinguish the source (demand or supply) and the magnitude of energy price influences on agricultural commodities (Chen et al., 2010). Of the studies which indicate a direct link between biofuels and agricultural commodity prices, they either employed models with a pre-built-in exogenous link between fuel and food, which is characteristic of CGE models or just assumed there is a relationship.

## 5.2 Current research trends

Other literature indicates more complex linkages with possible differing short- and long-run relations (Balcombe and Rapsomanikis, 2008 ; Diao et al., 2008; Daschle, 2007; Kerckow, 2007; Perlack et al., 2005; Prabhu et al., 2008; Webb, 1981; Senauer, 2008; and Zhang et al., 2010). This research indicates, in the short run, there probably is some causation between ethanol and agricultural commodity prices (Senauer, 2008; Zhang et al., 2009; Zhang et al., 2010). However, results indicate no long-run relationship. In support of these results, Esmaeili and Shokoohi (2011) indicate only a possible indirect relation between oil and agricultural commodity prices. Economic theory suggests global competitive markets will restore prices to their long-run equilibrium trends after any agricultural price shocks due to increased biofuel demand or other shocks (Figure 3) (Zhang et al., 2009; Zhang et al., 2010). As an example, using a world-market economic model, the rapid growth in biofuels will trigger a sharp rise in crop production at the expense of pasturelands and forests (Hertel et al., 2010). Further, Balcombe and Rapsomanikis (2008) found oil prices determine the long run equilibrium of both sugar and ethanol prices in Brazil. Sugar prices Granger-caused ethanol prices, but not the other way around. In the long run, farm prices (the prices of grains, dairy products, meats, and other farm produced commodities) and wages drive food prices. Claims that food prices are most strongly affected by energy price changes are not supported. Reducing energy prices will not reduce food prices (Lambert and Miljkovic, 2010). Furthermore, second and third generation biofuels have the potential to shift biomass production onto marginal croplands, reducing biofuel's food-price impacts.

### 5.2.1 Macroeconomic activity

This market response was a determinant in recent agricultural commodity price volatility: rising in 2007-2008, declining in 2009-2010, and then rising again in late 2010. Price volatility is also due to the heating up and cooling off of macroeconomic activity. Such activity is possibly the underlying cause of both food and fuel price instability (Kilian, 2009). Initial research in this direction, Balcombe and Rapsomanikis (2008) extend the supply-demand framework, which focuses only on biofuel and agricultural markets, by considering oil prices along with ethanol and sugar prices. Gohin and Chantret (2010) compared the relationship between the macro-linkages of the energy sector with the food sector, but do not consider biofuels. Additional research in this vein by Harri et al. (2009), Harrison (2009), Hayes et al. (2009), Sheng-Tung et al. (2010), and Yang et al. (2008) suggests a link between oil prices and agricultural commodity prices. Saghaian (2010) indicates that although there is a strong correlation among oil and commodity prices, the evidence for a causal link from oil to commodity prices is mixed. Considering five variables (oil, ethanol, corn, soybeans, and wheat prices) there are no causal links between the energy and agricultural sectors. However, the results of Granger causality tests indicate crude oil prices Granger cause corn, soybeans, and wheat prices.

When considering these global macro-linkages, international trade patterns and balances come into play. Hanson et al. (1993) have demonstrated that with fixed exchange rates and exogenous oil prices, U.S. agricultural commodity prices slightly declined with a doubling of crude oil prices; while with a fixed trade balance, farm prices increased. Saghaian (2010) also concludes that exchange rates are correlated with energy and agricultural markets, and attributes the correlation to oil prices denominated in U.S. dollars. A rise in oil prices increases the supply of U.S. dollars, which depreciates the dollar along with an increase in grain exports and higher food prices (Saghaian, 2010; Abbott et al., 2008).

Different baskets of agricultural commodities might lead to different conclusions on the relationship between the food and fuel prices. Imai et al. (2008) suggest the persistent impacts of a price change of oil on food might differ among countries and foods, and might be affected by the type of data used. For example, in China, their results indicate oil prices yield significantly positive effects on wheat and fruit prices, while imposing no effects on the price of rice and vegetables. In contrast, oil prices have positive effects on the India's price of wheat, rice, and fruit and vegetables.

### 5.3 Public policies

Public policies might be another important channel through which macroeconomic linkages of energy and food markets is built, especially in recent years. Those policies (including subsidies and mandates) are playing a more significant role in the interaction between food and energy prices, especially in developed countries such as the U.S. and EU (Von Braun and Torero, 2009; Gohin and Chanret, 2010; Balcombe and Rapsonmanikis, 2008; Vincent et al., 1979; Hanson et al., 1993). U.S. ethanol demand is mainly driven by government support, thus shocks to ethanol demand are considered as policy driven more than market driven (McPhail and Babcock, 2010). Senauer (2007) estimated that the U.S. \$0.51per gallon tax credit has distorted the food vs. fuel competition, making corn valued more as a fuel than a food input. Balcombe and Rapsonmanikis (2008) using Brazil as an example, found the growth of Brazil's ethanol market has been realized not only by the supply-demand linkage between the ethanol-sugarcane market, but also by various other factors including



government policies, technical changes, and the manufacturing of flex-fuels vehicles. Chen et al. (2010) indicate that production subsidies which encourage biofuel crops might result in significant impacts to the environment and the economy. They state that not only high oil prices but also government subsidies would result in a higher derived demand of corn-based ethanol, as well as price increases in various agricultural commodities.

#### 5.4 Modeling shortcomings

Specific channels of food and fuel interaction are not clearly defined or quantified. With current empirical methodologies and data, it is challenging to distinguish simultaneous supply-demand linkages and isolate impacts from macroeconomic variables. Insufficient theoretical understanding and observations among energy and agricultural commodity prices might generate misleading causal conclusions (Saghaian, 2010). As an example, without understanding the market channels linking agricultural commodity markets with energy markets, exogenous model elasticity assumptions may be invalid. Those shortcomings led to the post 2007-2008 forecasts of relatively high agricultural commodity prices when commodity prices actually declined (Figure 4). Theoretically understanding the simultaneous supply-demand linkage and isolating the impacts from macro effects may yield improved parameter estimates (Saghaian, 2010). Structural vector autoregressive models, such as Kilian (2009) and Mcphail (2010), may offer improved estimation techniques for investigating the co-movements of food and fuel variables. With endogeneity allowed, these techniques provide for the decomposition of demand and supply impacts.

Previous research generally specified linear models leading to pairwise linear correlations. As stated by Balcombe and Rapsomanikis (2008), oil, sugar, and ethanol markets could be treated as a nexus or perceived as separate when prices move within certain thresholds. Once prices fall outside a threshold, substitution effects between oil and ethanol would induce the transmission of price from market to market, introducing nonlinear behavior. Such threshold effects could be better captured by nonlinear models. Examples of nonlinear models are Balcombe and Rapsomanikis' (2008) use of Bayesian Monte Carlo Markov chains and Azar's (2003) use of a bottom up approach to investigate the competition between biomass and food. Alternatively, Baek and Koo (2009) and Chen et al., (2010) introduced structural breaks to divide the time-series data to capture the short-run and long-run impacts of energy prices and exchange rates on the food prices.

In summary, the literature solely investigating biofuel and food prices or the literature exogenously assuming a link exists suggest that indeed there is a direct and significant relationship between food and fuel. However, when considering more complex connections in terms of short- versus long-linkages and macroeconomic impacts such a direct relationship is questionable. Demand shocks, including sharp fluctuations in biofuel prices and macroeconomic shocks, and supply shocks in agricultural production probably do cause short-run agricultural commodity price inflations but not in the long-run. The underlying driver of both energy and agricultural prices is macroeconomic activity.

### 6. Policy

In this section, policy implications are addressed surrounding the hypothesis that the 2007-2008 food price spike was caused by the shift in global policies toward relying primarily on markets to provide adequate agricultural commodities in periods of sharp increases in food demand. This hypothesis and accompanying support from economic theory suggest in the

long-run markets will adjust to changes in crop usage, hence government policies such as food subsidies, price controls, and export restrictions are not warranted. However, in the short-run, due to inherent volatility throughout the food and biofuel production chains, tailored government policies are necessary to avoid future price spikes. As a reference for the discussion on both efficient and inefficient policies directed toward the food before fuel issue, a listing of policy prescriptions is provided in Table 3.

<b>Short-Run Policies</b>	
Economically Efficient	Completing negotiations on reducing agricultural trade restrictions Global food-price monitoring Precautionary agricultural commodity buffer stocks Emergency response and humanitarian assistance programs Educate consumers to expect greater food price volatility
Inefficient	Government incentives and regulations favorable to biomass production Policies directed toward maintaining fallow acreage
<b>Long-Run Policies</b>	
Economically Efficient	Allow free markets to adjust to changes in crop usages Constant infusion of public sponsored research and outreach Shift to sustainable perennial crops arresting topsoil erosion Improving energy efficiency Subsidize public transport Diversify food and fuel imports
Inefficient	Food and biofuel subsidies Price controls Export and import restrictions

Table 3. Policy Prescriptions

6.1 Long Run

6.1.1 Supply

6.1.1.1 Free Competitive markets

As indicated by economic theory and supported by empirical research, global competitive markets will lead to long-run stable agricultural commodity markets (Webb, 1981; Kerckow, 2007). U.S. farmers and technology will more than keep pace with demand not only for food but also for fuel (Daschle, 2007). Productivity gains for corn averaged nearly 3% per year, and the annual U.S. corn crop increased from 7 billion bushels in 1980 to nearly 12 billion bushels in 2006. However, competitive markets require a constant infusion of public sponsored research and outreach to maintain current productivity growth (Arndt, 2008; Christiaensen, 2009; Hochman, et al., 2008; Johnson, 2009; Prabhu et al., 2008; Rosegrant et al., 2008; Sexton, et al., 2009; Yang et al., 2008). Low levels of agricultural productivity in Africa are a major constraint to both poverty reduction and long-term economic growth



(Diao et al., 2008). Productivity gains in Africa are possible by increasing smallholder access to a modern package of inputs and management – improved seed, modern fertilizers and pesticides, and irrigation—along with enhanced integrated regional markets—low transportation costs, information systems, financial services, grades and standards, farmer and trader organizations, and commodity exchange systems (Diao et al., 2008; Kerckow, 2007; Prabhu et al., 2008). A shift to biofuels from mainly perennial, lignocellulosic plants and low input crops will contribute to a sustainable utilization of lower quality soils with limited water supply including degraded areas (Kerckow, 2007). However, there is concern that widespread planting of energy crops will accelerate the deterioration of the world's cropland base (Brown, 1980). In conjunction with advancing technology gains, efforts should be directed toward arresting topsoil erosion losses.

Providing more support to agencies such as the Consultative Group on International Agricultural Research (CGIAR) would be an important avenue toward stable food prices (Prabhu et al., 2008). In real 2008 dollars, U.S. investment in agricultural development abroad fell to \$60 million in 2006, down from an average of \$400 million a year in the 1980s. In developed countries, public investment in research, which had grown annually by more than 2% in the 1980s, shrank by 0.5% annually between 1991 and 2000. Global official aid to developing countries for agricultural research fell by 64% between 1980 and 2003. The decline was most marked in poor countries, especially in Africa. This reduction in investment is directly associated with reduced growth in agricultural productivity (Runge & Runge, 2010). A reason for this decline in public investment is that agricultural technology is difficult to ascribe to specific actions by a government and is unlikely to address the immediate impacts of food and energy price volatility (Arndt, 2008).

#### **6.1.1.2 Inefficient market controls**

The empirical relationship between biofuel and agricultural commodity prices suggests policies should be directed toward mitigating the short-run impacts on food prices. Effective adjustments require they send efficient market price signals. Imposing inflexible food subsidies or price controls distort market prices resulting in market inefficiencies leading to more volatile food prices and reduced security of the world's food supply (Collins and Duffield, 2005; Elam, 2008; Senauer, 2008). Food subsidies benefit consumers in the short-run, but at the expense of future investments due to the financial requirement for subsidization. Subsidies are not well targeted, are expensive, and exacerbate the burden of macroeconomic adjustment (Arndt, 2008). Price controls send negative price signals to producers that blunt the incentives for increasing supply (Johnson, 2009). More flexible policies should be designed that are responsive to agricultural and energy market realities (Elam, 2008). All such policy responses should reflect not just changes in world prices but also local price effects (Dewbre et al., 2008).

#### **6.1.2 Demand**

On the energy side of the equation, reducing the acceleration of global energy consumption and improving energy efficiency will lead toward sustainable energy and agricultural markets (Kerckow, 2007). U.S. and EU government policies providing incentives for biofuel production should be reconsidered in light of their impact on short-run food prices (Chen et al. 2011). As an example, increasing the U.S. Corporate Average Fuel Economy (CAFÉ) standard would cost approximately a third as much as it costs to subsidize ethanol (Doering, 2006). Alternatively, removing tariffs on ethanol imports in the U.S. and EU

would allow more efficient producers, such as Brazil and other developing countries, including many African countries to produce ethanol profitable for export to meet the mandates in the U.S. and EU (Arndt, 2008; Kerckow, 2007; Mitchell, 2008). Devadoss and Kuffel (2010) determine the current U.S. \$0.57 per gallon import tariff on ethanol should be a \$0.09 subsidy if the U.S. is interested in efficiently achieving the policy goals of reducing reliance on imported petroleum and reducing greenhouse gas emissions. An energy policy that more strongly emphasizes energy conservation is required (Elam, 2008). An example is subsidized public transport, but public transport passengers are typically not among the most vulnerable groups to high food prices, and such public subsidies are expensive and difficult to administer (Arndt, 2008).

U.S. government incentives and regulations favorable to biomass production, rather than investing in basic research and development for conservation and renewable sources of energy, enhance the profitability of biofuels over food (Runge and Senauer, 2007). Under current U.S. government incentives and regulations, the food vs. fuel choice is tilted toward fuel (Reilly and Paltsey, 2007).

## **6.2 Short run**

### **6.2.1 Trade liberalization**

For food importing countries, relying on agricultural productivity gains from other countries is a passive and risky policy. Instead they should consider watching their importing countries for possible major supply changes due to biofuel production or other factors and consider diversifying their agricultural imports (Brown, 1980). Food importing as well as exporting countries should work toward completing the Doha Round of World Trade Organization (WTO) negotiations leading toward more efficient agricultural free trade with regulations on food export restrictions (Christiaensen, 2009; Johnson, 2009; Von Braun et al., 2008).

Trade liberalization is much easier to administer than a subsidy and is consistent with a fundamental open economy policy. Non-price distorting policies include expanding social protection programs but such programs come with considerable cost or require a fundamental redistribution of income from the wealthy to the poor (Christiaensen, 2009; Prabhu et al., 2008; Yang et al., 2008). In the short-run, suspending ethanol blending mandates, subsidies, and ethanol import tariffs would cause a market response and lower agricultural commodity prices (Prabhu et al., 2008).

### **6.2.2 Global food monitoring with buffer stocks**

As far back as the 1980s it was suggested to establish a global food-price monitoring system that is sensitive to short-run price volatility from biofuel impacts or other market shocks (Brown, 1980). If such a monitoring system was in place prior to the 2007-2008 food price spike, the spike may have been avoided. However, instead policies were adopted that directly reduce supply by holding some acreage fallow as a way of reducing the cost of managing agricultural surpluses. The United States still has millions of acres enrolled in such programs. Those policies must be reconsidered in a world in which inventories have dwindled and critical food shortages can emerge and go unmet, as they did in the 2007-2008 food price spike (Johnson, 2009).

In conjunction with monitoring, global agricultural commodity stocks should be maintained to buffer short-run price spikes (Christiaensen, 2009). The dismantling of public food reserves led to the 2007-2008 food price spikes (McMichael, 2009). As in the

past, if government and private grain dealers had large inventories, the 2007-2008 food price spike would not have occurred. Food vs. fuel would have not been an issue. Recently, these precautionary inventories were allowed to shrink with the idea countries suffering crop failures could always import the food they required (Jha and Srinivasan, 2001). However, with no food in reserve, the global spike in food and biofuel demand resulted in a short-run rise in food prices when agricultural trade could not satisfy this world demand (Myers and Kent, 2003). World organizations including the International Monetary Fund and the World Bank have responded with policies and programs which commit funds for both immediate food aid and long-run increases in agricultural productivity (Singh, 2009).

Markets will adjust to shocks, but in cases of global supply shortfalls, such adjustments come at a high price of social discord and stress. The recent uprising in North Africa and the Middle East is predicated on high food price inflation. The aim is to avoid or at least buffer future price spikes by governments focusing on the public good to reinsure the global food supply (Christiaensen, 2009). An example where grain stocks were used to mitigate price increases is China's use of grain stocks to moderate the domestic price rise during the 2007-2008 food price spike (Yang et al., 2008).

However, in cases of localized food shortages or an unavoidable global price spike, expanded emergency response and humanitarian assistance programs are required to assist food-insecure people along with strengthened food-import financing. A closer look at the efficiency of current U.S. food aid programs also reveals many avenues for improved efficiency. The U.S. has been slow to change its food aid policies. As just one example, the U.S. currently requires a minimum share of its food aid be shipped on U.S.-flag vessels. This requirement costs U.S. taxpayers \$140 million in 2006, which is roughly equal to the cost of non-emergency food aid to Africa (Bageant et al., 2010).

### **6.2.3 Food vs. agricultural commodities**

The distinction between high world prices for agricultural commodities and the consumer costs of food is an important one. In developed countries consumers generally do not buy raw agricultural commodities at international prices. In many cases the proportion of agricultural commodity cost in their food is relatively small compared with the processing costs. In contrast, for consumers in many developing countries, the proportion of agricultural commodity to food costs can be large. Agricultural commodity price inflation will thus have a disproportionate effect on developed relative to developing countries. The degree to which the price of traded agricultural commodities and the price of food are related depends on factors that dampen price transmission. In the search for appropriate policy response, it is important to measure consumer effects correctly and to apportion properly the causes of current high food prices (Dewbre et al., 2008).

A final public action is to educate consumers to expect greater food price volatility, so they can adjust and plan (Yang et al., 2008). Without agricultural commodity supply buffers, food and agricultural commodity prices, particularly in the developing world, will continue to be volatile.

## **7. Summary and conclusions**

The chapter lays out evidence in support of the hypothesis that the 2007-2008 food price spike was not only caused by growing demand for biofuels but also by more complicated

macroeconomic factors, such as public policies. Literature is presented in a supply and demand framework. On the supply side, how energy inputs are affecting the agricultural sector in terms of production costs are reviewed. Conforming to economic theory, results indicate agricultural commodity prices are driven by production costs with higher prices of energy inputs implying higher agricultural production costs. However, care is required in concluding that higher energy prices directly imply higher agricultural commodity prices, especially in a short-run. Other factors (biofuels, trade restrictions, speculative demands, climatic events, higher demands, and lower stocks) besides oil prices affecting the cost of agricultural production may better explain agricultural commodity prices.

Within the supply-demand framework, two main methods (CGE and econometric approaches) are employed for food before fuel analysis. CGE models are widely adopted with a consideration of macro-linkages. However, they rely on exogenously determined elasticities among fuel and agricultural commodity variables. If these elasticities are not supported by theory and empirical evidence, the conclusions derive concerning the linkages among food, fuel, and other variables including global economic activity may be questionable.

In contrast, econometric approaches attempt to determine these linkages with Granger casualty tests, pairwise correlation matrixes, cointegration tests, and VECMs. Results suggest considering both the short-run price volatility of commodities as well as the long-run commodity price trends.

Implications from this literature review suggest a possible modification in the CGE models and other numerical models which may assume a direct long-run link between fuel prices and agricultural commodity prices. The resulting forecasts of high agricultural commodity prices precipitating from high fuel prices may be misleading. Based on time series results, a reshaping of these models may be in order. Yet the results have implications far beyond suggesting modifications in economic modeling. In the short run, it is important to ensure food availability to all, but most importantly to the global poor. Spikes in agricultural commodity prices, whether caused by biofuels, climate, or just human mistakes, cause irreparable harm to the global poor. Policies, including agricultural commodity buffers, designed to blunt these short-run price spikes should be reconsidered as a tool to reduce food volatility (Zhang et al., 2010).

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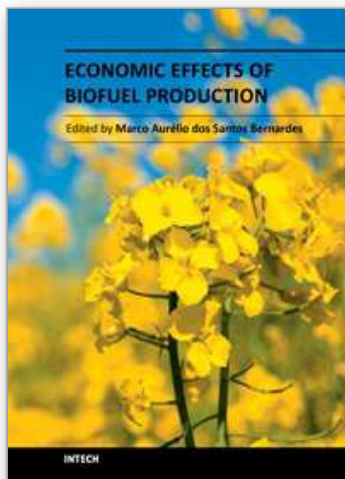
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## **Economic Effects of Biofuel Production**

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This book aspires to be a comprehensive summary of current biofuels issues and thereby contribute to the understanding of this important topic. Readers will find themes including biofuels development efforts, their implications for the food industry, current and future biofuels crops, the successful Brazilian ethanol program, insights of the first, second, third and fourth biofuel generations, advanced biofuel production techniques, related waste treatment, emissions and environmental impacts, water consumption, produced allergens and toxins. Additionally, the biofuel policy discussion is expected to be continuing in the foreseeable future and the reading of the biofuels features dealt with in this book, are recommended for anyone interested in understanding this diverse and developing theme.

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### **InTech China**

Unit 405, Office Block, Hotel Equatorial Shanghai  
No.65, Yan An Road (West), Shanghai, 200040, China  
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元  
Phone: +86-21-62489820  
Fax: +86-21-62489821



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