Is Biofuel the Culprit: OPEC food and fuel

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The food commodity price boom of 2003-08 was the most notable in the last several decades. It substantially impacted global economic activity. It affected developing nations by impacting real output, the balance of payments, government budgetary positions and most importantly the well being of the very poor (Troslte, 2008). High Commodity prices also affected developed countries, by transmitting business cycle disturbances and creating inflationary pressures (Borenzstein and Reinhart, 1994).

Several recent studies tried to identify and quantify the factors that caused the food commodity price boom of 2003-08 (FAO, 2008; Vansteenkiste 2009; among others). These studies suggest that growth in demand, which outpaced growth in supply since the 1980s, is a key factor. Other surveys argued that biofuel is the culprit, since it increases demand for staple crops (World Bank 2008; among others). All those studies assumed competitive markets and did not consider the impact of biofuel on energy costs to farmers. Moreover, they ignored OPEC. These studies leave us perplex regarding the true impact of biofuel on food commodity prices – was it or wasn't it an important contributor to the recent food commodity boom. We believe that to answer this question, the interactions between energy and food needs to be correctly modeled. In the process OPEC needs to be introduced, and the impact of biofuels need to be compared to other factors the literature argues are important.

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This paper aims to analyze the multiple contributions of energy and biofuels to the increase in food prices, within a multi-market framework. We decompose the energy impact on food commodity prices into two factors: the allocation of land to biofuel crops (which reduce food and feed availability and increase aggregate demand of food commodities), and the increase in energy prices (which increase production costs and reduce the supply of food commodities). OPEC affects both. Thus, in the process we introduce a new framework to analyze how OPEC affects energy prices, and how the introduction of alternative energy sources such as biofuel affects choices by OPEC. Moreover, to gain a perspective of biofuel's contributions to the food commodity price boom of 2003-08, we also assess the impact of growth in the demand for food commodities in China and India on food commodity prices.

Rajagopal et-al. (2007) showed that the first-generation of biofuels derived mostly from corn and sugarcane compete with food and feed, resulting in higher demand for agriculture commodities and thus higher prices. But the introduction of biofuels also lowers fuel prices (Rajagopal et al. 2007 and 2009). Yet, the literature failed to recognize that lower fuel prices affect farm level costs.

I. OPEC, fuel markets, and the price of food commodities.

Studies on the impacts of biofuels on food and fuel have assumed either that energy prices are fixed or that energy prices are competitive (e.g., Abbott et al. 2008; deGorter and Just, 2009; Rajagopal et al. 2009). The literature on oil market assumes that oil markets are either competitive or that OPEC is a cartel of firms (e.g., Adelman 1982; Griffin 1985). But OPEC is a cartel-of-nations (CON). Fuel prices are much lower in OPEC countries (where demand for fuel is more inelastic), in contrast to oil-importing countries. Although domestic policies can explain some of these differences, it cannot explain the systematic difference between OPEC countries and net importing countries. Whereas in 2006 super gasoline prices in non-OPEC countries equaled, on average, 1.04 US$ per liter, it equaled only 0.28 US$ per liter in OPEC countries (Metschies et al. 2007). Moreover, nominal subsidies went up in OPEC countries, at times when crude oil prices surged during 2002 to 2006 (Metschies et al. 2007). A similar pattern is observed for diesel prices.

The empirical study of Hochman and Zilberman (2008) showed that the wedge between oil price in OPEC nations and oil importing countries is consistent with OPEC being a CON, where OPEC countries maximize the joint domestic consumer and producer surplus from crude oil. We build on their work, and within a partial equilibrium model compute the equilibrium outcome, given that OPEC countries have monopoly power in international markets. In equilibrium, the marginal revenue to OPEC from oil exports equals domestic demand and the marginal cost of production. This results in a wedge between domestic prices in the oil-rich countries and in the oil importing countries. The wedge equals one over the absolute value of the import demand elasticity, such that domestic prices in oil-exporting countries are lower.

Crude oil is used to produce several products ranging from gasoline and diesel to asphalt and oil lubricants. In the United States from 1993 to 2008 65% to 67% of a barrel of crude oil is allocated to the production of gasoline and diesel.[1] These two products, characterized by relatively high profit margins when compared to other crude products, are an important source of income to downstream refineries. Thus, it creates strong incentives for refineries to maximize the amount of gasoline and diesel produced from crude, an amount that is constrained by

[1] http://tonto.eia.doe.gov/dnav/pet/pet_pnp_pct_dc_nus_pct_m.htm

technology.[2] Our analysis, therefore, uses fixed coefficients to derive fuel quantities from crude oil, and measure these quantities in gasoline equivalent gallons.

The biofuel industry, which is assumed to be competitive, is located at the oil importing countries. OPEC countries behave like a leading firm treating the biofuel industry as a competitive fringe. These assumptions capture the structure of the global fuel markets, whereby on the one hand crude oil extraction is concentrated in a region that does not produce biofuels, and on the other hand, trade in biofuels is concentrated among oil-importing countries. We assume oil and biofuel feedstock are measured in terms of gasoline-equivalent energy units. This normalization equalizes fuel prices and is consistent with the conceptual literature (de Gorter and Just, 2009; and Tyner and Taheripour, 2008). Furthermore, weekly data of gasoline and ethanol prices in Brazil does suggest that the price of ethanol is, on average, 30% lower than the price of gasoline (recall that the energy content of ethanol is 66% of gasoline). Note that allowing the difference between biofuels and fossil fuel prices to vary (say, due to binding biofuel mandates) does not alter the results qualitatively, although it does affect the magnitude of the difference between the price of fuel in oil-importing and oil-exporting countries.

The introduction of biofuels to the fuel markets causes the amount of fossil fuel (gasoline and diesel) consumed in the oil-importing countries to decline, the amount consumed in the OPEC countries to increase, and global fuel consumption (from crude oil and biomass) to increase. World fuel prices decline due to the introduction of biofuel, although the OPEC countries use their market power to mitigate the competitive impact of the introduction of biofuels (Hochman et al., forthcoming).

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[2] The evolution of the petroleum refinery industry is one where the main objective of technological innovations, dating back to the 1940s, is to maximize the amount of gasoline and diesel produced from a barrel of crude oil. See, for example, Leffler (2008) and Jones and Pujado (2006).

We incorporate this fuel market into a multi-market structure of the food commodities. The multimarket framework allows a partial disaggregation of crops to food, feed, and energy crops. This framework implies that fuel prices are endogenous and are affected by OPEC, and OPEC's response to the introduction of biofuels. It suggests that although biofuel increases demand for grains and sugar, it reduces the production cost by affecting the price set by OPEC.

II. Quantifying the conceptual model

While theory can predict the qualitative effects of biofuel on fuel, to derive policy recommendations, quantitative measures are also required. To this end, we conduct numerical analysis to quantify the effects of biofuel on fuel markets and its implication to prices of food commodities.

We assume an upward-sloping supply function for fuels. Whereas the upstream costs for a barrel of oil equivalent in the United States for onshore drilling equals 23.45 US$, it equals 57.20 US$ for offshore drilling. We also assume a linear demand and supply structures for food, feed and fuel. Because we focus on small biofuel shocks (recall that in 2008, biofuels equaled only 3% of global fuel markets), this numerical analysis is a good first order approximation to the effect of the biofuels on food commodity prices.

When modeling the impact of biofuels on energy costs, we distinguish between direct and indirect energy costs. Whereas agriculture uses energy directly as fuel or electricity to operate machinery and equipment, to heat or cool buildings, and for lighting in the farm, it uses energy indirectly in the fertilizers and chemicals that are produced off the farm but consumed on the farm. Crude oil dominates direct energy costs, while natural gas dominates indirect costs. The coefficients of energy use by source in agriculture production are taken from Schnepf (2004).

Using these coefficients, together with the relevant energy indices from the IMF,[3] we computed a weighted average energy cost index. This energy cost index affects the supply. For demand, we focus only on fuel prices since biofuels are used mostly for transportation.

Our analysis focuses on six major crops: maize, sugarcane, soybean, rapeseeds, rice, and wheat. Although production of each of these crops requires energy, only maize, sugarcane, soybean, and rapeseed are used to produce biofuels in large volumes. Therefore, although energy prices affect supply of all staple crops, fuel prices affect only demand for maize, sugarcane, soybean, and rapeseeds.

Because the distiller grain, i.e., the cereal byproducts of the distillation process (a process whereby water are separated from the ethanol, so the ethanol can be used as fuel), is an important co-product of dry-mill maize-ethanol production, we take into account the consumption of distiller grain while computing the impact of ethanol on maize prices.

We use secondary data on crop quantities and prices per region, collected from FAOSTAT[4] and USDA.[5] For each of the crops considered, we assume seven regions: Argentina, Brazil, China, the extended EU (27 countries), India, United States, and the rest of the world (ROW). Each one of the specific regions is either a main consumer, or main producer of at least one crop. The data is used to calibrate the model, and compute the demand and supply parameters.

To gain a perspective on the impact of fuel on food commodity prices, we compare the fuel impact to that of other factors. After calibration of demand and supply parameters that generate the observed equilibrium prices, we consider several alternative scenarios. They include

[3] http://www.imf.org/external/np/res/commod/index.asp
[4] http://faostat.fao.org/site/570/DesktopDefault.aspx?PageID=570#ancor
[5] http://www.fas.usda.gov/psdonline/psdQuery.aspx

reduction in biofuel production relative to the current levels – we consider three shocks such that biofuel quantities from a specific crop are reduced by 10%, 50%, and by 100%; an energy shock, where energy prices are held constant at their 2001 level; and a demand shock, where both China and India's growth in demand for food commodities would be 5% lower. These scenarios are computed assuming both a competitive oil market and a CON market structure. Using the market clearing conditions, we assumed one scenario at a time, and recomputed the energy and world food commodity price for each year, from 2001 to 2007.

The key parameters in these analyses are price elasticities of supply and demand, which measure the relative change in quantities supplied or demanded that result from a relatively small change in prices. We choose a range of plausible elasticities that are supported by the empirical literature (Krichene, 2002; Gardner, 1987),[6] and assume the elasticities are distributed uniformly on that range. The analysis then simulated 100 random draws, where for each draw we calibrated the model and computed the equilibrium price under the alternative scenarios. The average price for each scenario is then computed, and the percent change in prices relative to the baseline is computed.

III. The energy impact on food commodity prices

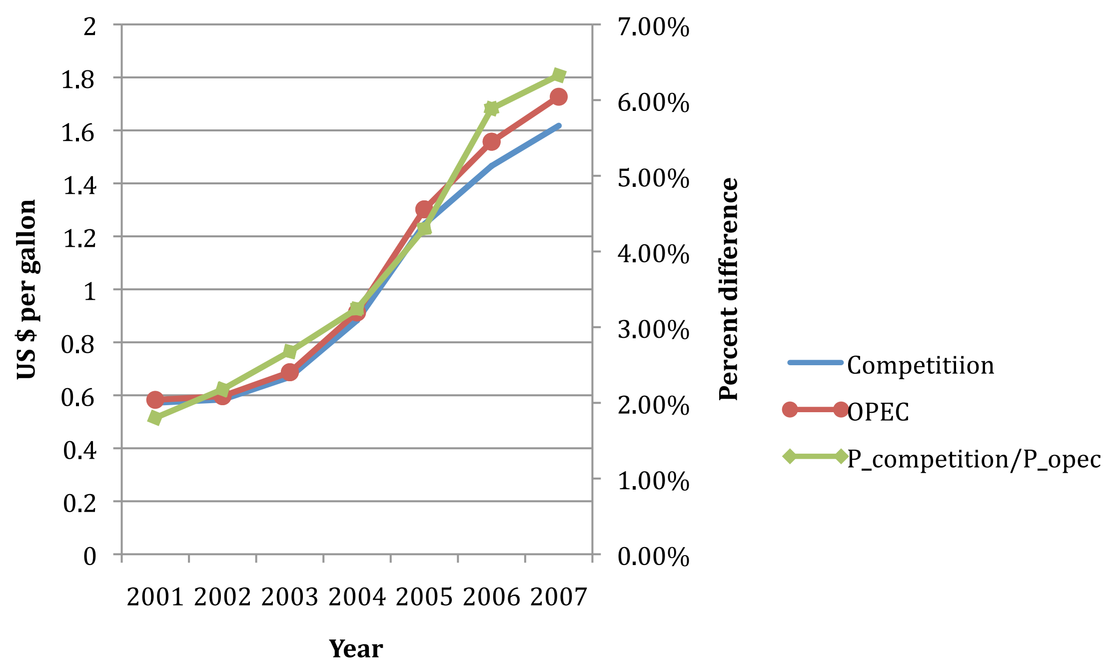
Results suggest that the current levels of biofuel production contribute to significant reduction in domestic fuel subsidies in OPEC countries and reduce prices of fuel in the rest of the world by about 3% (Hochman et al., 2009). The reduction in fuel prices has a direct effect on agriculture input prices, and an indirect effect of reduced monopoly power of OPEC. The latter effect is akin to an increase in the size of the competitive fringe in a leading-firm model. The leading firm

[6] See also http://www.fapri.iastate.edu/tools/elasticity.aspx

responds to increase in a competitive fringe by reducing quantities supplied, and similarly OPEC reduces production. This reduced OPEC supply lessens the fuel price reduction attributed to the introduction of biofuels.

Results suggest that introducing OPEC to the energy markets matters. Our simulations show that although the difference between the price of a gasoline equivalent gallon under competition and under OPEC is less than 1% in 2001, it reaches almost 7% in 2007 (Figure 1). From 2000 to 2005, world production of biofuels grew by 95% whereas world production of biodiesel grew by 295%.[7] Furthermore, although in 2005 7.95 billion gasoline equivalent gallons of biofuels were produced, it reached 12.69 in 2007.

Figure 1: Fuel prices



Computing the impact of biofuels on energy markets assuming the CON model is different than

[7] http://www.iea.org/techno/essentials2.pdf

impact computed when a competitive model is used. A competition overestimates the price effect, but underestimates both quantity and environmental effects attributed to the introduction of biofuels. The decline in fossil fuel consumed under competition is 44% less than what is suggested with the CON model, and the environmental effect of biofuels is underestimated by about 40% (Hochman et al., 2010).

OPEC also matters when evaluating the impact of the various factors on food commodity prices. A 50% reduction in corn ethanol would reduce the price of corn in 2007, such that the relative reduction in price would be 22% larger under competition. In 2007, reduction of corn ethanol would result in a price decrease of 7.19% under competition but only 5.87% under CON. We summarize these differences for the different crops and the different scenarios (biofuel, demand, and energy prices) in Table 1.

Table 1: Comparing the outcome of the different scenarios under CON and under competition

Scenario	Commodity price effect	2004	2005	2006	2007
Biofuel scenario:					
50% reduction in corn ethanol	**Corn**	-26%	-25%	-25%	-22%
50% reduction in soybeans biodiesel	**Soybeans**	-56%	-24%	-17%	-3%
50% reduction in rapeseeds biodiesel	**Rapeseed**	0%	0%	0%	0%
Demand scenario:					
5% reduction in demand for crop in China and India	**Corn**	1%	2%	2%	3%
	Soybeans	1%	2%	2%	3%
	Rapeseed	1%	1%	1%	2%
	Rice	1%	2%	2%	2%
	Wheat	1%	2%	2%	2%
Energy prices:					
2001 energy prices	**Corn**	4%	6%	8%	9%
	Soybeans	5%	6%	8%	9%
	Rapeseed	5%	6%	7%	8%
	Rice	4%	6%	8%	8%
	Wheat	4%	6%	8%	8%

As predicted by the conceptual framework, the impact of a reduction in biofuel on food commodity prices is larger under a competitive market structure than under OPEC. A reduction of 50% in crop allocated to biofuel production results in a bigger impact on prices if a competitive model is assumed. A large difference is identified in corn and in soybeans, but not in rapeseeds. Our results depend on the market structure assumed – CON versus competition -- and on the elasticities.

For example, choosing elasticity of demand and supply of -0.1 and 0.1, respectively, as opposed to a plausible range (-0.3, -0.2) and (0.2,0.3), results in much larger effects, albeit demand still emerges as a key factor. The impact of a 50% reduction in corn ethanol would result in a 15.35% decline in corn prices in 2007; about 300% higher than the plausible outcome computed below. Moreover, the price decline due to slower demand growth is now 33.88%, and the price decline with energy prices fixed at the 2001 level is 13.97%.

With respect to sugarcane, we limit the discussion to a 10% reduction in sugarcane ethanol. The reason is that sugarcane is used to produce ethanol from the 1970s, and a large part of sugarcane production is allocated to ethanol. A 10% reduction in the amount allocated to sugar ethanol is a large share of this market, and we want to focus on small changes around the equilibrium. The results are similar to the ones depicted in Table 1.

Biofuels also affect energy prices, since they impact OPEC’s pricing decisions. The price of crude oil, and thus the price of energy to the farmer, is different if CON and not competition are assumed. Our analysis suggests that this difference fluctuates between 4% and 9% (Table 1).

Fuel prices from 2001 to 2007 are higher under OPEC, and thus using 2001 energy prices results in a bigger impact under OPEC.

The impact of demand is larger if OPEC is incorporated into the calculations (Table 1). The magnitude, however, is small. The reason is that this difference is caused by the difference in energy prices between the two models. This suggests that as the share of biofuels in the global fuel market increases, the impact of the introduction of biofuels on fuel prices increases, and thus the difference between competition and OPEC will increase. These results depend on the elasticity chosen such that larger energy supply elasticity results in bigger impact for energy prices on production costs. Whereas using 2001 energy prices and assuming energy elasticity of -0.35 results in a 7.19% reduction in rapeseed prices in 2007, it is only 3% if the elasticity is -0.14.

Another difference between competition and CON is that OPEC introduces stability to the food commodity market.[8] In contrast to a market dominated by OPEC, the standard deviation of prices during 2001-07 would be 3% larger with a competitive market structure. The standard deviation would be almost 14% larger under the hypothetical assumption that the biofuel share in world fuel consumption is about 25%, as many predict would be the case in 2030.

When analyzing the effects of biofuel on food markets and domestic fuel consumers, we find that fuel consumers benefited from the introduction of biofuel- when it is subsidized, but less when its production is induced by mandates without subsidies. Food consumers suffered while crop producers benefited from high food prices (see also Rajagopal et al., 2009).

[8] Although OPEC introduces stability to the food commodity market, the inherent instability in staple crop production results in a biofuel industry with a boom-bust nature (Hochman et al., 2008).

Henceforth, we focus on the CON model. Reducing the amount of crop used for biofuel production by 100% resulted in a reduction of the food commodity prices (Table 2).

Table 2: ***The decrease in prices of under a scenario with 100% less biofuel from the specified crop***

	2005	2007
Corn	7.26%	12.18%
Soybeans	1.27%	3.96%
Rapeseed	57.37%	27.23%

Reducing the amount of corn allocated to ethanol by 100% would result in corn prices been 12.18% lower in 2007, but only 7.26% in 2005. On the other hand, reducing the amount of rapeseeds allocated to biodiesel production by 100% would result in rapeseed prices been 27.23% lower in 2007, but 57.37% lower in 2005. Corn production for ethanol increased during 2007, whereas rapeseed production in Europe decreased substantially in 2007. Overall, the net effect of biofuel polices on consumers and producers of food and fuel depends on assumptions about elasticities in various markets, the changes in farm productivity and the behavior of OPEC. More inelastic demand and supply elasticities result in a bigger biofuel impact on prices.

To understand the impact of biofuels on food commodity prices, we contrast these results with those obtain under a scenario where growth in demand for crops is 5% lower in both China and India (Table 3). In 2007, reducing demand in China and India would result in corn prices that are 17% lower, soybean prices that are 14% lower, and rapeseed that are 24% lower than the observed prices. With respect to rice, prices would be 40% lower, and wheat prices would be 21% lower. Assuming a counterfactual scenario, where demand is fixed at its 2001 level, will result in a much larger demand impact on prices.

Table 3: The decrease in prices under a scenario with smaller growth in demand in China and India

	2005	2007
Corn	11.85%	16.98%
Soybeans	9.40%	14.01%
Rapeseed	22.81%	23.68%
Rice	28.07%	39.77%
Wheat	13.02%	21.10%

Energy prices also contributed to the recent price commodity boom. Energy price index increased from 2001 to 2007 by more than 100%, and a major contributor to this spike are oil prices, which increased by more than 500% from 2002 to July 2008. The impact of fixing oil prices at 2001 levels is depicted in Table 4. Energy affects the cost of production, and in 2007 contributed between 5.56% to corn prices and 9.53% to sugarcane prices.

Table 4: The decrease in prices under a scenario with energy prices fixed at their 2001 level

	2005	2007
Corn	4.81%	5.56%
Soybeans	4.70%	5.44%
Rapeseed	5.44%	5.75%
Rice	7.65%	8.87%
Wheat	7.65%	8.86%

IV. Conclusion: Ag productivity and climate change

Our analysis suggests that, although energy had its impacts and the introduction of biofuel did make a contribution to the food commodity price spike, demand was the major driver in the food commodity price boom of 2003-08. Assuming conservative slower growth in demand for food commodities resulted in the biggest impact on prices, which in 2007 fluctuated between 17% and 40%. A counterfactual scenario, where demand is held fixed at its 2001 level, would have resulted in a much larger impact on prices.

Utilizing the CON model resulted in correct calculation for the impact of biofuel on food commodities. In the process, co-products are introduced into the calculation, and the impact of biofuels on fuel prices, and thus their impact on total production costs is modeled. Incorporating both factors into the analysis resulted in biofuel contributing around 10% to 15% to prices in 2007 (except for rapeseeds). Assuming both demand and supply for crops are more inelastic would, however, result in a larger impact on prices, which can exceed 20%.

Assuming energy prices are determined in equilibrium and are determined by OPEC, resulted in energy prices contributing about 8% to the price spike in 2007. Increasing the share of biofuels in global fuel consumption will result in lower energy prices, and lower production costs. Thus, second generation biofuels (which do not compete with food and feed) will substantially reduce the positive impact of the introduction of biofuels on food commodity prices. We, therefore, conclude that the importance of using the CON model, in contrast to competition, will only increase in the future. OPEC also stabilizes prices by reducing quantities supplied, which not only affects the environment (Hochman et al., forthcoming), but also translates to less food commodity price variability.

A major limitation of our analysis is that we looked at each market separately, rather than in an integrated manner. No cross-price elasticities were introduced, which led us to under-estimate the impact of biofuel on prices. Another limitation is that our analysis depends on elasticities. Given a plausible range for elasticities, our analysis suggests that the biofuel impact on prices is about 10%, but introducing very low demand and supply elasticities results in a larger impact that may equal 25% or even 30%. This suggests that good estimates of elasticities are important to compute the magnitude of the different factors. Other factors that need to be introduced, and are not introduced in this study, are speculation, domestic policies, depreciation of the US$, and inventory. In an on-going study, where we do introduce inventory, we find that low inventory levels trigger significant commodity price spikes.

The importance of demand in the food commodity price spike does suggest that agricultural productivity is crucial and should be improved, either by improving traditional farm practices or by embracing on biotechnology. Improving ag productivity and farming practices not only helps us make food available to more than a billion people around the world that go to bed hungry every day, but it can also help us combat climate change and carbon emissions.

References

Abbott, P.C. and C.A. Hurt and W.E. Tyner, “What's driving food prices?” *Farm Foundation*, 2008

Adelman, M.A., “OPEC Behavior and World Oil Prices,” in *OPEC as a Cartel*, 1982, pp. 37-63

Borenzstein, E. and C. M. Reinhart, “The macroeconomic determinants of commodity prices,” IMF Staff Papers, 41 (2), 1994, pp. 236-258

Dées, Stéphane and Pavlos Karadeloglou and Robert K. Kaufmann and Marcelo Sánchez, “Modelling the world oil market: Assessment of a quarterly econometric model,” *Energy Policy*, 35 (1), 2007, pp. 178-191

deGorter, Harry and David R. Just, “The Welfare Economics of a Biofuel Tax Credit and the Interaction Effects with Price Contingent Farm Subsidies,” *American Journal of Agricultural Economics*, 91 (2), May 2009, pp. 477-488

Food and Agricultural Organization, *The State of Food and Agriculture - Biofuels: Prospects, risks and opportunities*, 2008

Food and Agricultural Organization and EU, *Making food available*, **www.fao.org/europeanunion** 2009

Gardner, B.L. (1987). *The economics of agricultural*. Macmillan: New York, NY

Griffin, J.M., “OPEC Behavior: A Test of Alternative Hypotheses,” *American Economic Review*, 75 (5), 1985, pp. 954-963

Hochman, Gal, Steven E. Sexton and David Zilberman, “The Economics of Biofuel Policy and Biotechnology,” *Journal of Agricultural & Food Industrial Organization*, December 2008a

Hochman, Gal and David Zilberman, “OPEC, Gasoline Prices and the Optimal Export Tax Paradigm,” UC Berkeley working paper, 2008b

Hochman, Gal, Deepak Rajagopal, and David Zilberman, “The Effect of Biofuels on Crude Oil Markets,” *AgBioForum*, forthcoming

Krichene, N., “World crude oil and natural gas: a demand and supply model,” *Energy Economics*, 24 (6), 2002, pp. 557-576

Jones, D.S.J. and P.R. Pujad’o, *Handbook of petroleum processing*, Kluwer Academic: MA, 2006

Leffler, W.L., *Petroleum refining for the nontechnical person*, PennWell Books; Tulsa, OK, 2008

Metschies, Gerhard and Axel Friedrich and Falk Heinen and Jorg Peters and Sascha Thielmann and Gerhard P. Metschies, “International Fuel Prices 2007: 5th Edition - More than 170 Countries,” GTZ, 2007

Rajagopal, Deepak, Steve E. Sexton, David Roland-Holst, and David Zilberman, “Challenge of biofuel: filling the tank without emptying the stomach,” *Environmental Research Letters*, 2 (2), 2007, pp. 1-9

Rajagopal, Deepak, Steven E. Sexton, Gal Hochman, David W. Roland-Holst, and David Zilberman "Model estimates food-versus-biofuel trade-off," *California Agriculture,* 63(4), 2009, pp. 199-201

Schnepf, Randy, "Energy use in agriculture: Background and issues," Congressional Research Service Report for Congress, November 2004

Sexton, Steven E., Deepak Rajagopal, Gal Hochamn, David W. Roland-Holst, and David Zilberman, "Biofuel policy must evaluate environmental, food security and energy goals to maximize net benefits," *California Agriculture,* 63(4), 2009, pp. 191-198

Troslte, R., "Fluctuating food commodity prices: A complex issue with no easy answers," Amber Waves, 2008

Wallace, E.T. and F. Taheripour, "Policy options for integrated energy and agricultural markets," in *Transition to a Bio-Economy: Integration of Agricultural and Energy Systems*, Farm Foundation, 2008

Vansteenkiste, Isabel, "How important are common factors in driving non-fuel commodity prices? A dynamic factor analysis," European Central Bank Working paper series No 1072, July 2009