Agricultural and Resource Economics
UPDATE
GIANNINI FOUNDATION OF AGRICULTURAL ECONOMICS • UNIVERSITY OF CALIFORNIA
V. 12 no. 1 • Sep/Oct 2008

Food Versus Fuel: How Biofuels Make Food More Costly and Gasoline Cheaper

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This paper describes forces behind rising food prices and presents a model to characterize the magnitude of biofuel impacts on food and gasoline prices. The results of this model are compared to other estimates. We argue that a renewed commitment to agricultural productivity growth is needed to overcome current food and fuel challenges.

Also in this issue

In the next issue...

Special Issue: Causes and Consequences of the Food Price Crisis

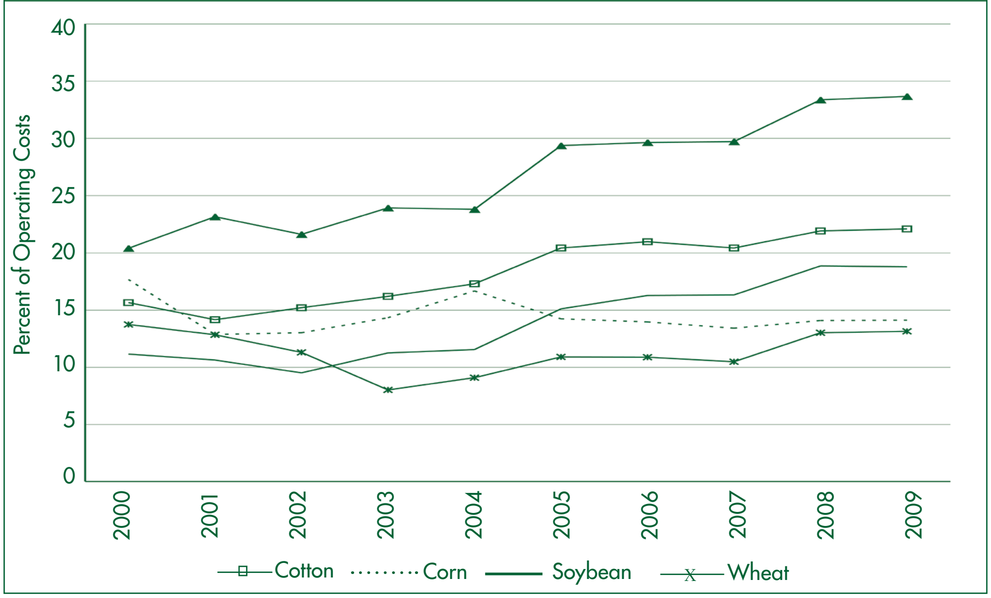
Biofuel production in the United States has been ridiculed in recent months, following the release of reports that suggest ethanol and biodiesel not only increase greenhouse gas emissions relative to fossil fuels, but also raise food prices and lower food production. The impact of biofuels on food markets came under particular scrutiny this year as the world entered its first food crisis in more than 30 years. It is certainly true that biofuels have increased the price of agricultural commodities, but the magnitude of biofuel impacts on food markets is unsettled. High food prices have been accompanied by record high oil prices, and, while biofuels have been blamed for exacerbating the former, they have not been credited with mitigating the latter. But just as surely as they have contributed to raising food prices, biofuels have helped reduce oil prices relative to prices that would prevail absent biofuel production. This article presents a model to demonstrate the effects of biofuels on corn, soybean, and gasoline prices, and to derive the distribution of benefits from U.S. biofuel production. We conclude that biofuels have a nontrivial impact on food security. We argue that underinvestment in research and overregulation of agricultural biotechnology led to a decline in productivity growth that is also responsible for higher prices and must be reversed if global food and energy security are to improve.

The rapid increases in food prices that began in 2007 have resulted in deadly food riots, increased robberies of food-aid caravans, export restrictions in grain-producing countries, and pleas for supplemental funding for food-aid programs. A 140 percent increase in food prices from 2002 to 2008 led humanitarian organizations to predict human suffering and starvation not seen in more than a generation. The Food and Agriculture Organization of the United Nations (FAO) reports food prices increased 53 percent in just one year from March 2007 to March 2008. Vegetable oils rose 97 percent, followed by grains, which rose 87 percent. Food price increases in the past year constitute the most rapid increase over a 12-month period in more than 30 years. The 55 percent increase in food prices in the past 12 months is exceeded only by their doubling from 1973 to 1974. The poor will suffer most from high prices because they devote large shares of their household budgets to food purchases. Even in countries where the rural poor benefit on average from higher prices for their agricultural output, the poorest of the poor will suffer.

Forces Driving Food Price Inflation

Biofuels are not solely responsible, nor necessarily principally responsible, for changes in the food security climate. A variety of supply-side and demand-side forces are at play. Among these is the

Figure 1. Fuel Costs as Share of Total Operating Costs



increase in oil prices in recent years. Oil prices have nearly doubled since 2006 from an average $66/barrel in 2006 to a forecasted average $116/barrel in 2008. Prices rose 60 percent in just the past year. These oil price increases raise the cost of agricultural production and transportation. Direct costs of fuel purchases have averaged about seven percent of farm operating costs since 1992, but have begun to rise as a share of costs in recent years. Figure 1 depicts the increasing fuel share of operating costs for five field crops (cotton, corn, soybeans, wheat, and rice) from 2000 to 2009 (data for 2007–2009 are forecasts). High fuel prices also raise the price of farm inputs, particularly those that are energy intensive, like fertilizers (70-90 percent of fertilizer costs are embodied in energy). As costs of production increase, the supply curve for agricultural commodities shifts up, raising market prices.

Table 1. Elasticity Assumptions for Simulations

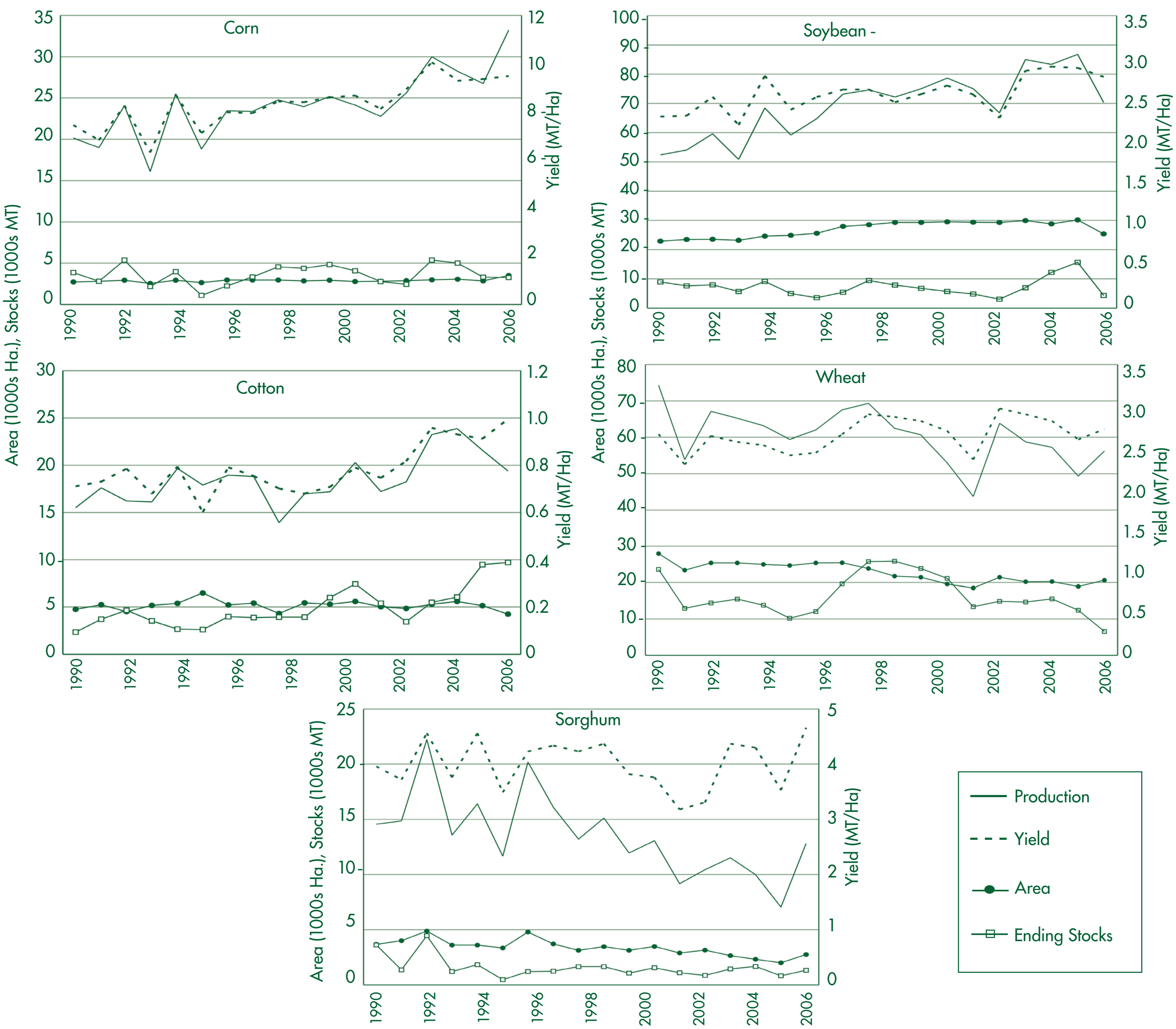
	Scenarios		
Own price supply elasticities	High	Mid	Low
Corn	0.5	0.4	0.3
Soy	0.5	0.4	0.3
Gas	0.3	0.4	0.5
Own price demand elasticities			
Corn	-0.5	-0.4	-0.3
Soy	-0.5	-0.4	-0.3
Gas	-0.3	-0.4	-0.5

On the demand side, population growth and income growth generate sustained upward pressure on prices. By 2050, the world population is expected to grow by half. Historically, such a rate of population growth was exceeded by agricultural productivity growth. From 1950 to 2000, for instance, per capita food production increased even as the world population doubled. This improvement in per capita food production occurred despite a shrinking agricultural land base because adoption of farming technologies like mechanization, irrigation, and chemicals promoted significant productivity gains. There is, however, little capacity for additional gains from these technologies, particularly in the developed world. New sources of productivity growth are needed to reverse a trend of stagnating yield gains. Agricultural biotechnology is one source of yield improvements, though it is underutilized and overregulated. Still, the effect of biotechnology cannot be missed when comparing yield trends for commodities planted to genetically modified (GM) seed and commodities not produced from agricultural biotechnology. Figure 2 shows persistent gains in productivity for corn, soybeans, and cotton—crops for which GM technology has been employed. Yields for staple crops like wheat and sorghum, however, are shown to have stagnated since 1990, as gains from the Green Revolution are exhausted. With slow productivity growth, food prices will be propelled higher by a rising world population and a shift toward meat-intensive diets induced by rising incomes.

Biofuels also increase demand for agricultural production. Biofuels have been supported by governments despite their inflationary effect on food prices because they are perceived to reduce greenhouse gas emissions relative to fossil fuels, improve energy independence, and spur rural development. As a consequence of favorable government intervention and energy prices that make biofuels cost-competitive with gasoline, global biofuel production has grown markedly in recent years, reaching 6,500 billion gallons in 2007—four times the production of 2000.

Existing biofuels are produced from agricultural crops traditionally used for food or feed. Ethanol, which dominates biofuel production in the United States and Brazil (and India to some extent), is presently produced from corn and sugarcane. Biodiesel, produced mainly in the E.U., is made from soybeans and rapeseed. Biofuel, therefore, increases demand for these staple crops so long as crop prices are not too high to make biofuels unprofitable. In 2007, 20 percent of the U.S. corn harvest was used in ethanol production and farmers planted the largest crop in 63 years—93 million acres—nearly a 20 percent increase from 2006. A second generation of biofuels will make use of energy-specific cellulosic crops that can be grown on marginal land. Cellulosic biofuels would reduce the diversion of food crops for

Figure 2. Production, Area Harvested, Inventories, and Yield for Staple Crops, 1990–2006

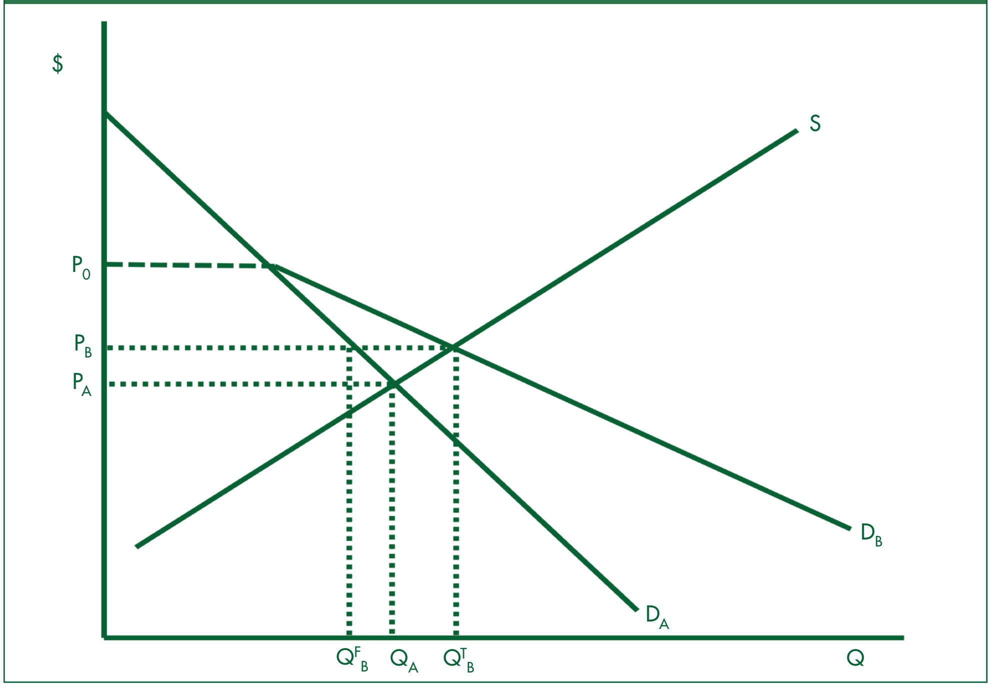


corn-ethanol and soybean-biodiesel, but they are yet to be commercially viable.

Biofuels also raise the costs of agricultural commodities not directly used in energy production. By raising demand for inputs in farm production, from tractors and fertilizer to water and land, biofuels raise production costs throughout agriculture. Perhaps nowhere is the pressure exerted by biofuels felt more acutely than in livestock production, a sector that faces rising costs for its primary input—feed. As biofuel raises the rental rate of land, feedstocks displace food crops and recruit idled land back into production. In doing so, it reduces the supplies of food and environmental preservation. The price boom since 2006 is also the result of tight markets with grain inventories at historic lows. A number of negative supply shocks to wheat and rice in recent years led to production shortfalls and caused a drawdown in crop inventories. Inventories act as a buffer to random shocks to markets, such as floods, droughts, or unusual pest pressure. When inventories are low, food prices are susceptible to any deviation in production from long-term trends, which may explain why wheat and rice prices increased more than corn prices in the past year.

Amid such tight markets and considerable uncertainty, rice-producing countries imposed export controls to protect domestic prices. Had production not exceeded expectations in 2008, the constrained international markets could have collapsed as more and more countries sought to insulate themselves

Figure 3. U.S. Corn Market



from higher and higher prices with greater export restrictions.

Quantifying the Effects

To estimate the impact of U.S. biofuel production on food and fuel markets and to determine the magnitude of welfare effects, we developed a global multi-market partial equilibrium model constituted by markets for corn, soybeans, biofuel and gasoline. We consider two regions, the United States and the Rest of the World (ROW), but assume that the responsiveness to prices of quantity supplied and demanded (elasticities) does not vary across regions. Using observed prices and quantities from 2007—when there was demand for biofuels—and assumptions on supply and demand elasticities, we constructed the counterfactual prices and quantities that would have prevailed absent biofuel demand.

Specifically, we assume demand for corn in the United States is composed of domestic ethanol demand, domestic demand for other uses (such as food and feed), and world excess demand. Figure 3 depicts the U.S. market for corn where demand is given by $\mathbf{D_A}$ with no demand for ethanol and $\mathbf{D_B}$ with demand for biofuel. $\mathbf{D_A}$ represents domestic demand for corn for uses other than biofuel and world excess demand. $\mathbf{D_B}$ also includes demand for ethanol, which is assumed to be zero above $\mathbf{P_0}$. We assume linear supply and demand for simplicity. Without biofuel demand, price is $\mathbf{P_A}$ and production is $\mathbf{Q_A}$. The quantity of corn for food and feed is $\mathbf{Q_A}$. With biofuel demand, the price is $\mathbf{P_B}$, production is $\mathbf{Q^T_B}$ and production for food and feed is $\mathbf{Q^F_B}$. The quantity of corn for ethanol is $\mathbf{Q^T_B} – \mathbf{Q^F_B}$. As can be seen by comparing equilibria with and without biofuel demand, biofuel demand increases the price of corn ($\mathbf{P_B} > \mathbf{P_A}$) and reduces the quantity of corn for other uses ($\mathbf{Q^F_B} < \mathbf{Q_A}$). We assume the U.S. market clears and determines the price for traded corn; the U.S. supplies 70 percent of traded corn. The soy, ethanol, and gasoline markets are modeled as described in Rajagopal et al. (See references on page 6.)

We provide results for three scenarios, which we call high, mid, and low, depending on the change in net consumer (surplus) due to biofuels. The high scenario is characterized by an elastic (price responsive) food market and inelastic (unresponsive to price) gasoline market. It is in this scenario that biofuel supply has the largest positive impact on gasoline consumers and smallest negative impact on food consumers. In the opposite scenario, characterized by a highly inelastic food market and a highly elastic gasoline market, food consumers suffer the most and gasoline consumers benefit the least. The mid scenario lies in between. The elasticities we use in the three scenarios are reported in Table 1.

Research suggests our "high" scenario may not be too optimistic and may, in fact, be conservative: elasticities for gasoline, soy, and corn tend to be less than 0.25 in the short run. Although we include the impact of biodiesel on the soy market, we do not estimate the impact of biodiesel production on diesel prices, which also serves to make our estimate of the fuel market impact of biofuels a conservative one.

Results and Discussion

Using data from 2007, in which 18.3 percent of U.S. corn production was used for ethanol, we find that ethanol raised corn prices at least 18 percent and perhaps as much as 39 percent, depending on elasticity assumptions. These results are summarized in Table 2, along with dollar savings per bushel, based on an average price of corn in the United States of $4.72/bushel in 2007. Under reasonable estimates, we

Table 2. Price Changes from U.S. Biofuel Production

	Corn Price Changes		Soybeans Price Changes		Gasoline Price Changes	
	Percent	$/ Bushel	Percent	$/ Bushel	Percent	$/Gallon
High	-15%	-0.72	-10%	-1.00	2.4%	0.07
Mid	-20%	-0.92	-13%	-1.34	1.8%	0.05
Low	-28%	-1.31	-20%	-2.02	1.4%	0.04

find that U.S. ethanol production in 2007 (4.4 billion gallons on an energy-equivalent basis) reduced gasoline prices at least 1.4 percent and as much as 2.4 percent, or $0.04 to $0.07 per gallon. These results are also reported in Table 2. The Energy Information Administration has estimated savings as high as $0.11 per gallon.

Based on this analysis, we find that under the most optimistic assumptions on biofuel impacts (our "high" scenario), gasoline consumers around the world benefited from lower gasoline prices by $41.7 billion. Consumers of soybeans and corn, however, lost $40.6 billion from higher food prices. On net, consumer welfare declined by $2.6 billion from U.S. ethanol production in the best-case scenario (after deducting the taxpayer cost of ethanol subsidies from the net consumer benefits). In the worst-case scenario, world consumers lost $54.8 billion in surplus. These results are summarized in Figure 4, while Table 3 summarizes welfare gains to U.S., foreign, and all producers and consumers under the three sets of elasticity assumptions. The total welfare in the United States (net U.S. consumer benefit + net U.S. producer benefit) improves by $0.9 billion with biofuel production under our optimistic ("high") scenario. But it declines under the other two scenarios. Likewise, total global welfare is improved under the "high" and "mid" scenarios by $1.7–18.2 billion, but falls under the "low" scenarios by $16 billion.

Our analysis demonstrates that biofuels reduce the price of gasoline to the benefit of gasoline consumers and confirms other reports that biofuels hurt food consumers. Ours is the only analysis to consider distributional concerns, which suggest a trade-off between fuel for the rich and food for the poor. Our analysis suggests biofuels are responsible for between 25–60 percent of recent corn price increases, which is consistent with reports from the President's Council of Economic Advisors (CEA), the USDA, and the Farm Foundation. These other studies generate a range in the share of food price increases attributable to biofuels of 23–61 percent.

Table 3. Welfare Effects of U.S. Biofuel Production (in billions of dollars)

	High	Mid	Low
Welfare Change			
World consumers*	-2.5713	-25.2875	-54.8611
U.S. consumers*	-3.8153	-10.2098	-19.1565
U.S. consumers net of tax*	-7.5303	-13.9248	-22.8715
ROW consumers*	4.959	-11.3627	-31.9896
World gas consumers	41.695	31.2709	25.0166
U.S. gas consumers	9.6271	7.2203	5.7762
ROW gas consumers	32.0678	24.0506	19.2404
World food consumers	-40.5513	-52.8434	-76.1627
U.S. food consumers	-13.4424	-17.4301	-24.9326
ROW food consumers	-27.1089	-35.4133	-51.23
World corn and soy producers	20.7519	27.016	38.8874
U.S. corn and soy producers	8.4425	10.9703	15.7465
ROW corn and soy producers	12.3095	16.0457	23.1408
Total U.S. Welfare Change	0.9122	-2.9545	-7.125
Total World Welfare Change	18.1806	1.7285	-15.9737

** Total consumer welfare change is the net effect of food and gas price effects. By region, the change in welfare for food consumers is added to the change in welfare for gas consumers.*

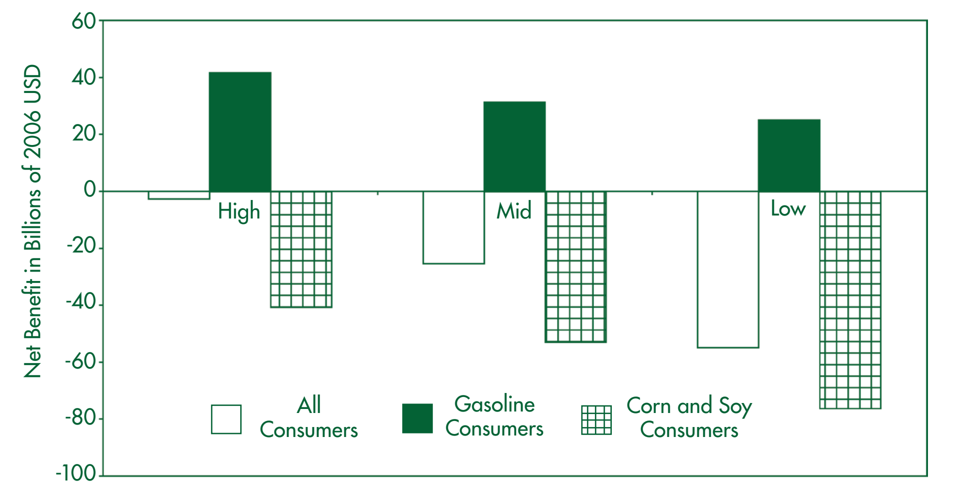
A report by the World Bank identified much larger impacts from biofuels on food markets. It found that biofuels were responsible for three-fourths of a 140 percent increase in food prices from 2002 to 2008, or roughly a 50 percent increase in the past year. This estimate is considerably higher than an estimate by the CEA that biofuels raised food prices 1.5 percent from 2007 to 2008. The World Bank analysis included indirect effects and long-term trends, while others did not. This may account for the magnitude of the World Bank estimate. The fall in stockpiles since 1990 can be seen in Figure 2 for five crops.

Depletion of stocks may be particularly responsible for remarkable price spikes since 2007. Biofuel production increased most dramatically in 2006 and 2007, and has not grown considerably in 2008. Yet food prices have risen most quickly and become most volatile in 2008. Interestingly, inventories for non-biofuel crops have fallen as much as or more than the stocks of biofuel crops (corn and soybeans), as seen in Figure 2. This suggests that slow productivity growth is an important factor in the decline of food security.

Biotechnology and the Food-Fuel Trade-off

Investment in agricultural research has declined in recent years, perhaps the result of complacency during a period of stable food prices. A lack of commitment to research and development can be blamed for declining rates of yield growth. Productivity growth since 1990 has been half as fast as it was from 1970–1990. It is expected to continue declining over the next ten years, according to the U.S. Department of Agriculture. From 1990–2007, the world population grew at a rate of 1.4 percent per year. Yields in grains and oilseeds grew at only 1.1 percent per year. Until 2017, yields are expected to grow at 0.8 percent, 0.3 percentage

Figure 4. Net Benefits to Gasoline and Food Consumers from Ethanol Supply in 2006



points less than forecasted population growth. These trends are ominous, given expectations for income growth and expansion of biofuel production.

Continued biofuel production and ongoing growth in food demand could cause a persistence of food security challenges. The food insecurity observed today is not a matter of inevitability, however. It can likely be overcome today and avoided in the future without abandonment of biofuels if the world regains its commitment to agricultural productivity growth and harnesses the potential of agricultural biotechnology. In the past 15 years, genetically modified (GM) crops have increased yields of cotton, rice, and corn 30–50 percent. GM crops are infused with genes to kill certain pests or provide immunity to common herbicides. They reduce the share of crops that is damaged and, thereby, improve productivity. With the demand pressures facing agriculture, biotechnology is an valuable mechanism for resolving an untenable food and energy situation. GM crops lessen the land constraint and permit greater production of food and energy crops on the existing agricultural land base.

Though GM crops have been adopted around the world at an astonishing rate, regulation, particularly in Europe, has reduced the market for agricultural biotechnology in recent years. This has not only slowed yield growth from existing technologies, but also slowed development of next generation genetically modified seed that is expected to introduce drought-tolerant plants and staple crops infused with additional nutrients like beta-carotene. Without a market for their innovations, however, there is little incentive for firms to invest in agricultural biotechnology R&D.

Conclusion

World agriculture is facing great challenges as growing demand for food and fuel creates scarcity and induces hunger. Even when considering just U.S. biofuel production, it is clear biofuels have significantly reduced gasoline prices, but at the expense of contributing to food shortages. The challenge for agriculture to meet growing food demand and growing energy demand requires all the tools available to improve productivity, including agricultural biotechnology. It also creates urgency for the development of commercially viable cellulosic biofuel technologies that reduce demand for staple crops and make more efficient use of resources than current technologies.

The development of second generation biofuels may take some time and productivity gains from biotechnology may be gradual. Therefore, it will be necessary to develop mechanisms to fight food shortages in the short-run. One mechanism that should be considered is a food fund that could be tapped into to buy food for the poor in crisis situations. Another option may be to tie government support for biofuel to food market outcomes. When food production falls too low, subsidies and mandates should be scaled back to protect against hunger. Policymakers may also find it necessary to reconsider existing policies in light of the current food situation. They and researchers must recognize that the management of agriculture is increasingly becoming a balancing act between energy, environment, and food objectives.

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The authors wish to thank Colin Carter, Gordon Rausser, and Aaron Smith for helpful comments. This research is funded by the Energy Biosciences Institute and Farm Foundation.

For more information, the authors recommend the following:

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