Food, Feed, or Fuel?

Examining Linkages Between Biofuels and Agricultural Market Economies

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As global energy resources become increasingly scarce in the face of growing energy demand for transport fuel and other productive uses, many countries have begun to turn to the possibilities that biofuels from renewable resources could offer to supplement their domestic energy portfolio. While much of the recent literature has focused on the growth of biofuels in the developed world—mostly in ethanol, a substitute for gasoline made from sugar- or starch-based crops, and biodiesel, a substitute for diesel made from oil-based crops—developing nations have expressed growing interest in biofuel production as well.[1] Although Brazil and the United States currently represent nearly 90 percent of ethanol production, and the European Union represents 90 percent of biodiesel production, China and India are expected to capture a growing share of production in these biofuels categories in the coming decades.[2]

While a number of other developing countries find the prospect of biofuels attractive, the degree to which they invest in building capacity for their own domestic production remains uncertain, given the fluctuating price of fossil-based energy and the inevitable long-term commitment of governments to support fledgling biofuel-producing industries through subsidies, tax credits, and other producer and consumer incentives. There are a number of countries in sub-Saharan Africa, South and Southeast Asia, and Latin America that have suitable climates, agro-ecological conditions, land areas, and water resources for growing the crops required for biofuel production, also known as feedstock.[3] However, the degree of infrastructure development in these countries varies widely, and many nations are incapable of competing against those which are able to facilitate the large-scale production of biofuels. Furthermore, the extent to which some developing countries would need to divert scarce resources away from other important development projects and, in general, a broader agenda for growth, serves as an argument against the adoption of biofuel technologies in the immediate future.

In their recent agricultural outlook to 2016, the Organization for Economic Cooperation and Development (OECD) and the Food and Agriculture Organization (FAO) suggest that biofuel production is the principal driver of long-term commodity price trends.[4] These price effects may be strong enough to shift consumption patterns for the world's poor, rendering more people food insecure. As a result, policymakers have examined the effects of increased biofuel production on commodity prices. While elucidating producer price incentives, these studies do not develop a full picture of how energy, growth, and consumption are interrelated. Although some countries are viewed less as "developing" nations—like China, which seems well on its way to meet such important Millennium Development goals as reducing poverty and hunger—there is still concern that developing countries might jeopardize their goals of improving human well-being for the poorest if they aggressively pursue agriculturally-based production of biofuels. For example, rapid economic growth in India coincides with high levels of poverty and food insecurity.

We address the body of literature that looks at the rapidly increasing biofuels production and demand within both the developed and developing world, and the potential for adverse impacts on global food economies. Energy-driven economic growth illustrates the linkages between agricultural production, consumption, and the productivity of capital and energy in meeting the needs of the economy. This approach highlights the tradeoffs in land use, and the implications that arise for food growing capacity. Moreover, we can observe how the dynamics of "food-versus-fuel" play out under alternative growth paths and their resulting policy implications. Ultimately, policymakers and researchers should better understand the complexities of biofuel production in order to synergize investment and development strategies that strengthen the function of food systems.

Overview of Current Literature.

Much of the current literature focuses on the impacts of increased biofuel production on crop prices and land use. For major food exporters in Latin America, a paper prepared for the American Association of Agricultural Economics annual meeting determines that producers have enough excess land to produce for food and fuel.[5] For OECD countries, between 30 and 70 percent of current cropland would have to be dedicated to biofuel production to offset a 10 percent domestic demand for transport fuel.[6] Concerning prices, OECD also predicts that the additional demand for ethanol could increase the world price of sugar by 60 percent before 2014.[7] Msangi et al., however, demonstrate that the strong increases in feedstock commodity prices are lessened as second generation technologies go on-line.[8] Other studies note the difficulty in determining whether increasing producer price incentives will be substantial enough to overcome escalating production costs as a result of higher oil prices.[9]

The price effects of biofuel production have also been found to differ by feedstock commodity. Such is the case even though the causal linkages tend to be similar and stem from the increased demand of feedstock, leading to tighter market conditions and higher prices for the commodity. In Latin America, for example, differing price effects are projected for bioenergy crops, traditional crops, and bioenergy production by-products such as soy meal.[10] Indeed, strong downward price effects have been observed for protein rich feedstocks, including soybeans and cereals, which have protein-rich by-products.[11] In addition, other studies have found strong downward impacts on world cereal and oilseed markets by changing baseline growth rates for major agricultural markets.[12]

While the underlying mechanisms dictating commodity price effects have yet to be fully explored, there remains strong interest in determining how biofuels may affect food security. Countries that import both food and fuel tend to have the least secure food supplies because net food exporters have the potential to produce both food and fuel, while net importers have to decide whether to import food and produce bioenergy or vice versa.[13] Conversely, countries that have strong export markets in non-food-related sectors, such as tourism, may be able to absorb higher import costs.[14] Similarly, urban households that purchase both food and fuel may have a considerable disadvantage in adjusting to increases in food prices, compared to rural residents who are able to produce food or fuel for their own consumption.

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Higher agricultural prices may give rural producers access to world energy markets, but few studies investigate their impacts on food consumption and nutrition. For example, sugarcane and cassava provide the most viable feedstocks for ethanol production in Latin America.[15] Rosegrant et al., however, predict that a rise in production of cassava-derived bioethanol may cause a near tripling of its world price by 2020, posing a serious threat to the many rural poor who depend on cassava as a staple crop.[16]

Interactions between Energy and Food Markets. In this section we discuss the linkages between energy and agricultural markets, the implications that growth in energy and food demand have on land, and the need for technological improvements. These linkages show the role that technology plays in improving both the conversion efficiency of crop-based biomass into energy, as well as the productivity of agricultural crops themselves. Both of these factors underlie the relationship between growth in biofuel production and its impact on agricultural economies, revealing trade-offs with food availability and consumer welfare.

Agricultural production in the developed world is highly mechanized, maximizing yield with manufactured inputs like fertilizers and improved seed varieties. Each of these factors requires energy directly for fueling farm equipment and indirectly as inputs to manufacture fertilizers and machinery. Even though modern agriculture depends on energy-based inputs, food prices remain low through a combination of low input costs and high yields. High energy prices, however, are increasing the costs of production. Consider, for example, the linkage between energy markets and the market for fertilizer. Since energy poses a significant input cost for producing fertilizer, a change in energy price has a direct effect on the price of fertilizer. An increase in fertilizer price will cause a decrease in the amount of fertilizer demanded at the farm level. As a result, the quantity of food available on the market will decrease, forcing consumers to pay higher prices. Similar linkages can be drawn for other energy intensive farm inputs, such as machinery and other equipment, which would have significant impacts on agrarian households when considered together.

Land is another main factor of agricultural production. The decision to dedicate land to the production of biofuels depends heavily on available conversion technologies, or the processes that transform crops into fuels. Current technologies can efficiently convert grains and sugars—such as corn and sugar cane—into ethanol, and oils—such as those derived from soybeans—into biodiesel. The efficiency of these technologies depends on the yield, in bushels per acre, of the feedstock to the energy content per gallon processed. In the United States, corn is transformed into ethanol at a rate of 2.5 gallons of ethanol per bushel, with an average yield of 139.34 bushels per acre.[17] This means that the average producer can generate 350 gallons of ethanol per acre of corn cultivation.

To further illustrate how biofuel production is linked to land use, and ultimately crop production and productivity, consider the effects of two simultaneous technological improvements: one in fuel conversion technologies, and another in agricultural productivity. The shift in fuel conversion efficiency allows a greater amount of energy to be produced for the same amount of land—or, conversely, the same amount of energy with a lesser amount of land. As conversion technologies become more efficient, a decreasing amount of land will be necessary for energy production and, in turn, more will be available for food crops. Additionally, as agricultural productivity improvements are made in improved seed varieties or mechanization, increased yields will result from the same amount of land. Under this scenario, more land can be dedicated for energy production without affecting food production yields.

From this example, we see that the concurrence of increasing food production—to meet the needs of growing, wealthier populations—and increasing energy demands places steeper requirements on the improvement of both energy and crop technologies in order to keep up. Otherwise, a constant or decreasing food supply from the decreased availability of land for food production and static yields would cause the "food-versus-fuel" trade-off that is of much concern to policymakers and analysts. When formulating policy, it will be important to consider how simultaneous improvements in both fuel conversion and crop productivity influence the evolution of energy production and yield levels over time in relation to the quantity of total agricultural land available for food or energy uses.

Extensification, an increase in total agricultural land, could relieve some of the constraints that might be placed on yield growth and might be an option where there is non-agricultural land that could easily be converted. Of course, care has to be taken to ensure that expansion into non-agricultural land would not entail losing important habitats for species or propelling fragile lands toward rapid declines in quality. Several such instances occurred in tropical and semi-tropical environments, where clearing for agriculture disrupted the delicate ecologies of forested areas—its result, the rapid loss of soil, organic matter, and fertility, and a subsequent degradation of livelihoods dependent upon those lands. These kinds of dynamics illustrated the differences between North American soil ecologies and those of tropical South America and Africa—the latter rarely appreciated by early aid efforts, which promoted large-scale, prairie-style modes of grain production.[18] In the past, the livelihoods of non-agricultural, indigenous communities were also overlooked when considering options for expanding production into low-density areas, leading to social disruption and the subsequent loss of tradition-based livelihoods.[19]

There might also be concerns about animal habitat preservation that could arise if large-scale extensification were considered an option for increasing cultivated areas for energy crops. Together with possible disruption and loss of important eco-system functions, habitats could be destroyed if environmental considerations were not weighed and valued accordingly in the larger cost-benefit calculations driving investment decisions. These shortcomings could be partially addressed by involving key stakeholders in the evaluation process, strengthening the regulation and enforcement of land use, where such mechanisms exist, or creating them where they do not.

But most heavily populated regions have already reached the limits of their cultivable land due to the pressures of urbanization and human settlement—especially if one wants to farm on land that has access to water and market infrastructure as opposed to low-quality and highly degraded lands. This would make the intensification of production on existing land—leading to higher productivity levels—the only viable option for some regions to increase their output of food, feed, and biofuel feedstock, while maintaining the ecological integrity of the surrounding landscape.

Implications for Food Security and Policy. Many of these country-level investments coincide with those that we might consider generally necessary for the improvement of food production, distribution, and delivery systems in developing agricultural economies. A multitude of the environmental stresses that could stand in the way of crop production for biofuel feedstocks, in terms of soil quality or other critical resource endowments such as water, are the same stresses that put pressure on the production of food for domestic consumption and export. Indeed, many of the preconditions for establishing an efficient and well-functioning domestic biofuel program, such as reliable agricultural storage, processing, distribution systems, and high-yielding agricultural production systems, are the same ones that policymakers and researchers consider when trying to define the necessary conditions for food security and the reliable delivery of food-based services to developing country populations.

In light of this coincidence, it would appear that the "food-for-fuel" trade-off, that some policy analysts argue would result from the large-scale expansion of biofuel production, need not occur. Indeed, the very investments that might enhance food security through the strengthening of food production and delivery systems—such as higher-yielding, input-intensive cropping where production and processing take place within a vertically integrated and capital-intensive system—could be the very ones that ensure the healthy operation of a nascent biofuel industry and prevent the kind of sharp trade-off that some predict. Undoubtedly, there will be market-level price effects when there is a large-scale expansion of production from feedstock commodities that also has sizeable food and feed use value, and surely those who are most vulnerable to price increases could be adversely affected. However, the need for continued policy analysis in this area is clearly evident and should remain a research priority.

Conclusions. Devoting resources to biofuel production affects agricultural production, economic growth, overall socio-economic development, and human welfare. We describe the key linkages between agriculture and energy to illustrate the important technological factors affecting the long-term prospects for the biofuels industry and its impact on the economy. Development and long-term economic growth will inevitably lead to more capital- and energy-intensive patterns of production over time, and it remains the role of technological efficiency improvements in both industry and agriculture to relieve the pressures that this growth will place on the natural resource base and the landscape. A food-focused economy would need much more agricultural land, barring any productivity improvements, than one that is more capital- and energy-intensive. However, the linkages between growth, consumption, and energy needs will inevitably put greater pressure on production systems, and on the natural resources and ecosystems that support them.

Therefore, maintaining a focus on agricultural productivity and technological innovation in agricultural and other sectors can help avoid the "food-versus-fuel" trade-off. The duality of biofuel capacity growth and agricultural development allows for a synergy between these goals, such that more efficient and productive agricultural production, processing, storage, and distribution processes can lead to better outcomes in food security and the productive capacity of the biofuels industry. By examining biofuel capacity, agricultural development, and economic growth in this way, we can achieve a multitude of important human development goals with a common set of technologies, policy instruments, and interventions.

NOTES

1 Worldwatch Institute, "Biofuels for Transportation: Global Potential and Implications for Sustainable Agriculture and Energy in the 21st Century," Extended Summary of Report for the German Federal Ministry of Food and Agricultural and Consumer Protection (BMELV), Washington DC, 2006.

2 Lew Fulton, Tom Howes, and Jeffrey Hardy, *Biofuels for Transport: An International Perspective* (Paris: International Energy Agency, 2004).

3 World Bank Energy Sector Management Assistance Program (ESMAP), *Potential for Biofuels for Transport in Developing Countries*. Report 312/05 (Washington, DC: World Bank, 2005).

4 "Agricultural Outlook 2007-2016," Organization for Economic Cooperation and Development/Food and Agricultural Organization of the UN, 2007.

5 Carlos E. Ludena, Carlos Razo, and Alberto Saucedo, "Biofuels in Latin America and the Caribbean: Quantitative Considerations and Policy Implications for the Agricultural Sector," Paper prepared for the American Association of Agricultural Economics Annual Meeting, Portland, Oregon, 29 July-1 August 2007.

6 Organization for Economic Cooperation and Development, "Agricultural Market Impacts of Future Growth in the Production of Biofuels, 2006," http://www.oecd.org/home (date accessed:10 August 2007).

7 Ibid.

8 Siwa Msangi, Timothy Sulser, Mark Rosegrant, and Rowena Valmonte-Santos, "Global Scenarios for Biofuels: Impacts and Implications," *Farm Policy Journal* vol .4, no. 2 (2007).

9 Josef Schmidhuber, "Impact of an Increased Biomass Use on Agricultural Markets, Prices, and Food Security: A Longer-Term Perspective," Paper prepared for the International Symposium of Notre Europe, Paris, 27-29 November 2006.

10 Ludena et al., "Biofuels in Latin America and the Caribbean."

11 Schmidhuber, "Increased Biomass Use."

12 Catherine Benjamin and Magalie Houee-Bigot, "Measuring Competition Between Non-Food and Food Demand on World Grain Markets: Is Biofuel Production Compatible With Pressure for Food Production?" Paper prepared for the American Association of Agricultural Economics Annual Meeting, Portland, Oregon,29 July- 1 August 2007.

13 Ludena et al., "Biofuels in Latin America and the Caribbean;" Schmidhuber, "Increased Biomass Use;" C. Ford Runge and Benjamin Senauer, "How Biofuels Could Starve the Poor," *Foreign Affairs* 86, no. 3 (2007): 41-53.

14 Schmidhuber, "Increased Biomass Use."

15 Ludena et al., "Biofuels in Latin America and the Caribbean."

16 Mark Rosegrant, Siwa Msangi, Timothy Sulser, and Rowena Valmonte-Santos, "Biofuels and the Global Food Balance," *2020 Focus 14—Bioenergy and Agriculture: Promises and Challenges*, eds. Peter Hazell and R. K. Pachauri (Washington: International Food Policy Research Institute, 2006).

17 Ben Harden "Improving Ethanol Yield From Corn," *Agricultural Research*, October (1996), Internet, http://www.ars.usda.gov/is/AR/archive/oct96/ethanol1096.htm (Date accessed: 10 October 2007); Shapouri, Hosein, and Andrew McAloon, "The 2001 Net Energy Balance of Corn-Ethanol," U.S. Department of Agriculture, 2001, http://www.usda.gov/oce/reports/energy/net_energy_balance.pdf (date accessed: 15 October 2007).

18 S.A.Vosti, J. Witcover, and C.L. Carpentier. 2002. "Agriculture Intensification by Smallholders in the Western Brazilian Amazon: From Deforestation to Sustainable Land Use," *Research Report 130*, (International Food Policy Research Institute: Washington, D.C.).

19 Charles R. Lane, and Jules N. Pretty. 1991. *Displaced Pastoralists and Transferred Wheat Technology in Tanzania*. Gatekeeper series, no. 20.(London: Sustainable Agriculture Programme of the International Institute for Environment and Development).