ENERGY, EQUITY, AND AGRICULTURAL DEVELOPMENT

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Energy is intricately related to agricultural production. Plants capture solar energy and convert it into food, energy, and other products useful for mankind. Agriculture is potentially a source of not only food, feed, and fibre, but also of energy. Agriculture is also an important user of energy. Technical progress in agriculture has meant more intensive use of commercial energy in agriculture. The rapid escalation of energy prices in the 1970s has important efficiency and equity implications for agriculture. This paper reviews the relationships between energy and agriculture with agriculture as both a producer and a consumer of energy.

Energy Use in Agriculture

In traditional agriculture, solar, animal, and human energy were the only energy inputs in agricultural production. Modernization of agriculture has meant the addition of other forms of energy, such as fertilizer, mechanical power, and irrigation, which increase the efficiency of photosynthetic conversion of solar energy to stored chemical energy. Technical change in agriculture has produced high yielding crop varieties whose main advantage is their great responsiveness to fertilizers and irrigation. Increasing agricultural production, particularly in developing countries, thus implies increasing the use of energy intensive inputs such as fertilizer and irrigation.

Commercial energy use in agriculture varies significantly among countries and regions. The level of commercial energy use is highly correlated with crop yields (table 1). Output/input ratios are much higher for the developing countries than for the United States, but even in energy intensive crop production in the United States, net energy is produced by agriculture. Yields per hectare are much higher in the United States, reflecting particularly the greater use of energy intensive inputs. The higher energy output/input ratios for developing countries indicate that there is large potential for increasing crop output by increasing use of commercial energy inputs such as fertilizer and irrigation. Increasing dependence on commercial energy may seem paradoxical in an age of energy shortages and rising prices. But it is essential if agricultural production is to increase sufficiently to meet the world's growing food needs.

Table 1. Commercial Energy Use for Selected Crops, 1975

Location	Crop	Yield (ton/ha)	Energy use (kg oil equiv/ ha)	Energy use (kg oil equiv/ ton)	Energy output/ input (kg. oil equiv/ kg oil equiv)
90 Developing countries	Wheat	1.28	42.8	33.4	10
	Rice	1.98	55.1	27.8	12
	Maize	1.39	37.9	27.2	13
United States	Wheat	2.33	137.8	59.1	6
	Rice	5.09	1,054.6	207.2	2
	Maize	5.54	455.4	82.2	4

How will the demand for commercial energy in agriculture change over the next 20 years? The agricultural system of developing countries will become more commercial energy intensive during the next two decades with each percentage increase in agricultural output requiring about a 2.1-percent increase in commercial energy use. Commercial energy use for agriculture in the year 2000 in developing countries will be four to five times the 1980 level. FAO projects commercial energy use in agriculture to grow 6.7-8.0 percent per year, with fertilizer accounting for 60 percent of the total increase.

Total commercial energy use in developing countries is projected to grow at about 6.1 percent per year (World Bank). Since agricultural energy use is projected to grow somewhat faster than this rate, the share of commercial energy used in agriculture is expected to rise. Agriculture will be competing with the industrial, transport, and residential sectors for sometimes scarce and expensive energy supplies. If food production is to grow close to the rates postulated by FAO, policymakers will have to ensure that agriculture receives the needed commercial energy inputs--even at the expense of the politically powerful urban areas.

One of the important policy and equity issues of the next decade will be managing the allocation of scarce energy supplies in developing countries. Many of the agricultural energy inputs such as fertilizer and pesticides will be imported or imported raw materials will be used to produce them, so that despite the very high productivity of increased commercial energy use in agriculture, there is a risk that supplies will be inadequate. The equity implications of this tradeoff are quite important. Urban energy consumers, particularly car owners, tend to belong to upper income groups, while rural agricultural producers are often in middle or lower income brackets. More important, restricted availability of commercial energy inputs for agriculture means lower food production and higher food prices, which will hurt the poor relatively more than the rich. Despite these likely equity implications of tilting energy supplies towards urban areas, it may be politically difficult to avoid such an allocation. One important task for agricultural economists in the decade ahead will be to estimate the equity as well as the efficiency consequences of alternative energy allocation policies.

Agriculture as a Source of Energy

As little as 100 years ago, biomass (primarily wood) was the major source of energy in most of the world. Biomass is still the major source of energy in many developing countries. Biomass energy as a proportion of total energy consumption ranges from 2 percent in the United States to 96 percent in Nepal. Biomass energy is roughly half of total energy consumption in India and Guatemala, 30 percent in Brazil and China, and about 74 percent in Bangladesh. With the recent increases in energy prices, there is a heightened interest in the use of biomass and other alternative sources for energy in developing and developed countries alike. The total amount of biomass produced each year by photosynthesis is enormous--more than all commerical energy consumed in the world, yet only a very small fraction of this resource is available for energy use. If the entire 1978 world production of grains, sugar, and root crops had been converted to fuel alcohol, it would have amounted to only 6 percent of total commercial energy consumption in that year (FAO, p. 75). Energy production from agriculture thus has limited potential within our total world energy picture; yet, for some raw materials and in some countries, biomass energy does now and can continue to make an important contribution to total energy supplies.

Yet there is significant potential to dramatically increase fuelwood production. Managed forests can produce up to six times the annual yield of unmanaged natural forests (FAO, p. 75). Energy costs for fuelwood from managed forests are today generally competitive with other alternatives. One of the great difficulties is to get a sustainable managed forest or woodlot system established when serious fuel shortages obtain. Villagers have strong incentives (like survival) to harvest the fuelwood before it reaches sufficient maturity to enter a sustainable yield cycle. Also, fuelwood demand from adjacent areas means that any small localized programme is doomed to failure. Space does not permit a detailed discussion of the equity issues involved in the fuelwood problem, but it is clear that the poorest of the poor are seriously affected, and that there is little hope for agricultural development in these regions unless the fuelwood problem is solved.

Alcohol Fuels

In addition to fuelwood, there is considerable interest in the potential of converting crops, crop residues, and other cellulosic materials into alcohol fuels. Crops most commonly mentioned are coarse grains, sugarcane, and cassava. Potential cellulosic feedstocks include forage grasses, crop residues such as maize stalks and cobs, sugarcane bagasse, wood, and even municipal solid waste. Alcohol production programmes have been launched by several countries. Brazil is the world's largest alcohol producer, currently making about 5 billion[2] litres of alcohol per year from sugarcane. The United States is making less than 1 billion[2] litres per year from maize.

The cost of making ethanol from any of these sources is higher than the equivalent cost of imported petrol. Alcohol from most of these sources costs at least $0.35 per litre or $15 per million BTUs ($14/gigajoule). Costs of alcohol from some of the cellulosic sources exceed $0.50/litre. Alcohol has about two thirds the energy of one litre of petrol. Petrol costs about $0.30 per litre or about $8.70 per million BTUs ($8.25/gigajoule). A recent study concluded that production of alcohol from maize or cellulose in the United States would not be economic until the late 1990s even with oil prices rising at 3 percent per year in real terms (Hoff and Tyner). Countries which have embarked on alcohol programmes have done so for reasons other than cost. It is commonly argued that domestic alcohol production will reduce oil imports, increase the stability of balance of payments, stimulate rural development, and increase rural incomes. Much of the argument for alcohol production from biomass then rests on recognizing that equity gains outweigh efficiency losses. However, the total equity impacts of alcohol production are not at all clear. To the extent that alcohol production diverts land away from food and feed production, significant food price increases could result. Hoff and Tyner concluded that U.S. production of about 15 billion[2] litres of alcohol per year from maize could cause an increase in the world maize price of 4-5 percent, with related increases in other crop prices. Other studies have indicated even higher price increases. Hence, if a major exporter of grains embarks on a large alcohol programme, significant increases in world food prices could result. At the same time, a smaller U.S. programme would be unlikely to cause any major price changes because of the existence of excess production capacity. Similarly in Brazil, to the extent that sugarcane expansion occurs at the expense of food crop production, the supply of food crops like black beans will fall and their prices will rise.

In both Brazil and the United States, alcohol production is heavily subsidized. The alcohol is used in both countries to provide power for cars. The effect of the subsidy is partly to transfer income from food consumers to liquid fuel consumers. The equity impact of this transfer depends on the proportion of income spent on food and on liquid fuel by income class. It is clearly possible that these alcohol production subsidies effect a transfer from the relatively poor to the rich. However, we do not have nearly enough information to draw a definitive conclusion. We would need to obtain data on changes in income and employment in rural areas and from the alcohol distilleries. We would need to estimate the share of the expansion in sugarcane or maize areas which comes from new land and the proportion which comes at the expense of production of other crops. The point is that the alcohol programmes are being implemented to accomplish equity objectives, but we do not know what their equity impacts are.

Scale of Production

There is much interest in the scale of production and conversion facilities. It is commonly believed that small scale is more equitable. A vast literature has emerged on on-farm alcohol technology, and small farm or community alcohol production facilities are being promoted extensively. In Brazil, there is concern that large alcohol plants with sugarcane coming primarily from land owned by the mill will serve to concentrate alcohol production benefits in the rich, landowning classes.

However, there is no need for the scale of production of the raw material to be the same scale as for conversion. A very large alcohol plant could obtain raw material from numerous smallholders located near the plant. In that way, the benefits of agricultural energy production could be distributed more evenly and the efficiencies of large scale conversion retained. The basic problem with small scale alcohol conversion is not higher capital cost per unit of gross capacity, but the efficiency of conversion. Whether the raw material is maize or sugarcane, the conversion efficiency is considerably lower at small scales resulting in alcohol costs often 30 percent higher than from large scale plants. Also, recent studies have concluded that small scale alcohol production is not as economic as small scale production of a diesel-like fuel from oil seeds. Reining and Tyner compared three different small scales of sunflower oil production with similar scales of alcohol production. In every case, the sunflower oil was cheaper than the alcohol per unit of energy produced (but not cheaper than diesel fuel). The sunflower oil can be used directly as a substitute for diesel fuel in diesel powered tractors.

Two points are worth emphasizing. First, the scale issue is not as simple as it may appear, and there may be means of distributing the development benefits of an alcohol programme without losing the economies of scale of conversion. Second, all available alternatives should be examined before choosing a particular biomass resource. Oilseeds may be preferable to sugarcane or maize for liquid fuels (at small scale), wood is likely to be better for process heat, and small scale hydropower may be preferred for electricity.

Efficiency-Equity Analyses of Biomass Energy Alternatives

Economists often avoid equity analysis because it is so difficult to do. But it is clear in this case that we need to do more empirical research on the equity-efficiency tradeoffs involved in biomass energy production--especially for alcohol fuels. Some very large alcohol programmes are being undertaken, despite the high cost of alcohol, to accomplish equity objectives. Even relatively simple equity assessment could be of use just in understanding the kinds of equity impacts that occur. A good starting point might be the Floyd approach to evaluating the impacts on factor shares of U.S. farm policies.

Use of renewable agricultural crops for energy production is in many countries an emotionally charged issue. Agricultural energy production has the potential of increasing employment and incomes of 70 percent of the people in developing countries who live in rural areas. Use of agricultural resources for energy also has the potential to lead to significant world food price increases. Where between these poles the result actually lies depends on a large number of factors. One important factor is supply response to higher crop prices, or long term elasticity of supply. Unfortunately, we know very little about supply response, particularly in developing countries. We have seen decades of constant or declining real prices of agricultural crops, just as we had for energy before 1973. And just as was the case for energy, we know very little about the production. response to higher real prices which might be brought about by energy demand for crops. It will be very important, then, for us to carefully monitor the changes which occur in countries that use crops for energy and to increase our research on supply response under these conditions.

Another important factor is country diversity. Biomass liquid fuels programmes may be well suited to one country and not at all suited to another. Data on level of oil imports, land availability, food imports, labour supply, capital availability, institutional constraints, and other factors would be needed to decide if biomass liquids fuels production should be seriously considered in any given country.

Conclusion

Even though agriculture uses a small share of total commercial energy (3-4 percent) and the potential of agriculture to produce liquid fuels is quite small, energy issues will loom large in agricultural economics in the next decade. Increased commerical energy use is essential for needed agricultural production increases. At the same time, agriculture could supply increased amounts of commercial and noncommercial energy. In both cases, equity concerns appear to be just as important as economic efficiency in the decisions that are being made. Our task in the decade ahead is to improve our empirical research on the efficiency-equity impacts of policies that are being considered or implemented.

Notes

[1]Purdue University, West Lafayette, and FAO, Rome.
[2]Billion as used here equals 1,000,000,000 [eds.].

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