Measuring Unmeasurable Land-Use Changes from Biofuels

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The debate over whether biofuels are good for the environment used to hinge on the credibility of studies published by David Pimentel, professor of ecology at Cornell University, who concluded that it took much more energy or fossil fuel to grow, transport, and process corn into ethanol than the ethanol could ever hope to replace as transportation fuel. A preponderance of other studies on the issue found the data and methods used by Pimentel to be suspect, and most concluded that biofuels generally, and corn ethanol specifically, have a positive net energy balance, and their use as a replacement for gasoline leads to a reduction in greenhouse gas emissions.

The debate about whether biofuels are a good thing now focuses squarely on whether their use causes too much conversion of natural lands into crop and livestock production around the world. The worry is that the loss of carbon stocks on the converted land would more than offset the direct reduction in greenhouse gas emissions caused by lower gasoline use. The California Air Resources Board (CARB) has concluded that corn ethanol causes such large amounts of land conversion that it does not qualify as a low-carbon fuel. In its recent analysis of greenhouse gas emissions from biofuels, the U.S. Environmental Protection Agency (EPA) estimates that corn ethanol and biodiesel made from soybean oil cause enough land-use changes to call into question whether these biofuels meet required greenhouse gas reductions.

The debate over land-use changes caused by biofuels has two main threads. The first is a policy question focusing on whether the United States should even account for land-use changes in other countries when considering greenhouse gas regulations of biofuels. The second is on the actual measurement of land-use changes and whether the models used by CARB and EPA are accurate enough to support regulations that have billion-dollar consequences on the biofuels industry.

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Most of the audience in the debate over measurement of the land-use impacts of biofuels has little understanding of the approach that is used by CARB and EPA to estimate land-use changes from biofuels. Hence, it is difficult for most to judge whether the approach is accurate enough to justify its use. An overview of the procedures used to estimate indirect land use should help clarify the most important issues involved.

Why Are Economists Doing the Measuring?

The three groups that have been most involved in estimating land-use changes from biofuels are economists at Iowa State University, Texas A&M University, and Purdue University (see the Editor's note at the end of the article). Economists are involved because land-use changes from biofuels expansion is a response by farmers and other landowners to a change in the supply of crops available to meet non-fuel demands. The economic story for corn ethanol is as follows. Expansion of U.S. corn ethanol production increases the demand for corn. This demand increase causes the market price of corn to rise. The increase in the price of corn causes U.S. farmers to grow more corn. Growing more U.S. corn can be done by increasing yields on existing land, by allocating more land to corn and less to other crops, and by creating more farmland. Cutting acreage to other crops can lead to price increases for these crops also. Because agricultural commodities are traded worldwide, the price changes for corn and other crops seen in the United States will also be seen by farmers in other countries, thereby affecting their agricultural supplies. Those farmers around the world who see higher market prices will also increase yields, reallocate land among crops, and bring new land into production.

Each step of this corn ethanol story requires an economist to estimate the likely response of farmers, livestock producers, the food industry, other industrial users of agricultural commodities, and non-farming landowners to a change in market price. The key factors that influence how much land is converted to cropland include the following:

- Which crops will U.S. farmers decrease in response to higher corn prices?
- How much U.S. pasture and forest land will be converted to crops?
- How much will farmers increase yields in response to price?
- How much will prices, demand, and production change in each important producing

or consuming country in response to a change in U.S. production and exports?

Economists understand that the answers to each of these questions depend greatly on how much time passes before the response is measured. For example, a $1.00-per-bushel increase in the price of corn will cause almost no U.S. land to be converted from pasture or forest to cropland after a single year. But a sustained $1.00-per-bushel increase for five years will likely result in some land being converted. Similarly, supply and demand in other countries will respond a great deal more after five years than after one year.

Economists also understand that the precision with which these responses can be measured depends greatly on the quality and availability of data. We have a fairly good idea of the response of U.S. livestock producers to higher feed costs: given enough time, livestock supplies will be reduced, resulting in higher meat and dairy prices. But economists' ability to estimate how Brazilian cattle ranchers will respond to the resulting increase in demand for Brazilian beef is less precise. The Brazilian cattle sector is simply less well understood than the U.S. livestock sector (even by Brazilian economists). The sector has had less scrutiny, and data measuring its performance and structure is much less developed.

More often than we want to admit, economists face situations in which we do not have adequate data to make precise estimates of the response of a sector to a price change. The backup strategy is to rely on economic theory to determine the direction of the response, and then to make a reasonable assumption about the magnitude of the response. For example, as anybody who has taken Econ 101 knows, supply curves slope up. This means that the quantity supplied to the market will increase if market demand increases. Thus, economists know that the Brazilian cattle herd will increase by some amount if U.S. meat supplies decrease. But an informed judgment about the magnitude of the change will rely on a trade economist looking at Brazilian trade policy to determine the extent to which a change in U.S. meat supplies will affect Brazilian prices. Then an experienced agricultural economist will know something about the cattle cycle and estimate how long it might take for the Brazilian cattle herd to respond to a price increase. A dedicated Brazilian agricultural economist with detailed knowledge of Brazilian environmental enforcement mechanisms will then make an estimate of the extent to which pasture can expand in frontier forests. This estimate will then be linked with the cattle cycle and the price transmission to come up with an informed estimate of the timing and extent to which the Brazilian cattle herd will change in response to an increase in feed prices caused by biofuels expansion.

Most of the parameters used to capture supply and demand responses to price changes that populate the models economists use to estimate the impact of biofuels on land are based on less detailed knowledge than the given example assumes. Rather, estimates are based on previous work (the applicability and quality of which is typically not addressed), insight of the analyst, and overall "reasonableness" with respect to the problem at hand. Economists need not apologize for constructing models in this manner: it simply is the only way to proceed because of a lack of data and specialized knowledge about agricultural and food systems around the world.

One implication of this reliance on a combination of theory and judgment is that it is quite difficult to construct confidence intervals around model predictions. The distribution of most model parameters is not known because most are not estimated statistically. Furthermore, those parameters that are taken from the original studies in which they were estimated are generally not directly applicable to the new use for which they are being gathered. Thus, there is no way that model predictions can be tested statistically.

Modelers will conduct sensitivity analyses in recognition of the uncertainty underlying key model parameters. The parameters are varied from what might be considered reasonable lower and upper bounds on their values, and then model predictions over the parameter range are calculated. Although useful as a way to identify which model parameters are most important in determining outcomes, this procedure cannot be represented as a statistical test of the model.

Why Model Predictions Will Not Be Consistent with History

One criticism of the models used by CARB and EPA to estimate indirect land use is that their predictions of land-use changes seem not to track with the actual changes in land use that we have observed in the last few years in response to sharply higher biofuels volumes. One might hope that the land-use changes we have seen could be used to validate or discredit the model predictions. For example, two recent studies (Tokgoz et al. 2007 and Hertel et al. 2009) of the impact of expanded biofuels on U.S. and world agriculture both estimate that expansion of corn ethanol would be accompanied by a large increase in corn production, a large decrease in soybean production, and significant decrease in corn and soybean exports. History differs from these predictions. Since 2005, corn ethanol has increased by about six billion gallons. Corn acreage has increased by about 6 percent, which is consistent with predictions. But soybean acreage has increased by more than 7 percent, corn exports are projected to be flat in the 2009/10 marketing year, and soybean exports are projected to increase by more than 25 percent. The model predictions completely missed the large expansion in U.S. soybean production that has accompanied corn ethanol expansion and the ability of the United States to maintain or expand its exports of corn and soybeans.

The problem with comparing actual outcomes with model predictions is that they are not comparable. The impacts of biofuels are estimated by modelers relative to what their models predict will be the agricultural situation under a baseline volume of biofuels, and under a set of assumptions about future macroeconomic growth, growing conditions, crop yields, exchange rates, and government policies. The models are then re-run with a higher biofuels volume and the same set of conditioning assumptions. By subtracting the model results with higher biofuel volumes from the baseline model results, modelers hope to isolate the effects of biofuels expansion because all other factors that affect the agricultural economy are held constant.

But of course, economic growth, weather, yields, exchange rates, and policies change every year. Thus, the projected agricultural situation will never line up with what actually occurs. The hope of modelers is that estimates of the change in production and market prices caused by biofuels expansion relative to baseline projections of production and prices are robust to changes in the conditioning assumptions. So even if the commodity boom and bust, the worldwide recession, and the major drought in Australia have moved agriculture away from its projected path, modelers assume that their estimated impact of biofuels on production and prices remain valid.

One advantage that modelers have is that their estimates are largely irrefutable because the world that they use to make their projections is never actually observed. For example, the expansion of U.S. soybean acreage since 2005 would seem to refute model predictions about how U.S. farmers would adjust their acreage in response to expansion of corn ethanol. But we will never know because we cannot re-run history with lower ethanol volumes. If we could, it may well be that U.S. soybean acreage would have been much larger than it actually was, in which case the model predictions would be correct. Because model predictions cannot be refuted by past data, the credibility of models relies on submitting the models and results to peer review, being transparent about model assumptions and parameters, and putting in place a process by which the models reflect the latest knowledge about agricultural and food systems.

New Uses for Agricultural Models

Perhaps economists' greatest social contribution is their ability to anticipate unintended consequences of seemingly good policy ideas. A classic unintended consequence is the market response of producers and consumers to a price change. When agricultural intervention is large enough to affect prices, then we must anticipate that there will be a response. And if the affected prices are for commodities that are traded, then some of the response will occur in other countries. The fact that the world will respond to a U.S. policy that diverts 30 percent of an expanded U.S. corn crop from other uses to biofuels is not surprising. Predictions that expanded biofuels will cause expansion of cropland are not new. For example, in 1992, researchers at the Center for Agricultural and Rural Development conducted a study on the implications of increased cellulosic biofuels production and concluded that "higher crop prices in the biomass scenarios induce a conversion of nonagricultural land to crop production" (Reese et al. 1992).

What are new are legislative mandates to quantify the response of the world agricultural system to U.S. biofuels policy, with severe financial consequences for those biofuels having estimates of unintentional consequences deemed too great. The models that have been employed to estimate changes in domestic and international crop acreage have not traditionally been used in a regulatory context. Rather they have been used to give policymakers an idea of the likely consequences of changes in agricultural and trade policy. As a guide to policy development and understanding, these models have proved invaluable in facilitating policy agreements. The jury is still out on their use as a regulatory tool.

Economists know that agricultural supply curves slope up and that expanded agricultural production will require some additional land. This means that expansion of U.S. biofuels will result in more land being devoted to crop production on an aggregate worldwide basis. However, given all the forces that affect agricultural production decisions, it is impossible to attribute any given agricultural development project to U.S. biofuels expansion, which is why CARB and EPA have to rely on models that attempt to isolate the effects of U.S. biofuels.

The financial stakes involved in the estimation of land-use changes from biofuels have created a large incentive for interest groups to know more about the models and the approaches that are used. Those whose interests have been harmed by model estimates will have an incentive to identify and change model assumptions and approaches that will serve their interests. Given the lack of data and detailed knowledge about exactly how the world's producers and consumers will respond to a change in U.S. policy, the models used to estimate land-use changes are populated with parameters that reflect judgment calls, modeler insights, and economic wisdom rather than hard data. Thus, these models,

Continued on page 11

Costs and Benefits to Agriculture from Climate Change Policy
Continued from page 3

dairy farms that produce the equivalent of five tons of CO_2 reductions per year per cow. At a price of $20 per ton, this generates $100 per cow per year. Of course, any net benefit or net cost of using and capturing the methane must be added or subtracted from this $100. For comparison, the same cow may produce 20,000 pounds of milk per year, which generates perhaps $1,000 per year in milk revenue in excess of feed costs at a milk price of $15 per hundredweight.

Is Agriculture a Net Winner or Loser from a Carbon Cap-and-Trade Policy?

If the United States adopts a cap-and-trade policy to combat climate change, the negative impacts on agriculture will likely be relatively small, particularly if agricultural emissions remain uncapped. Once companies here and abroad have a profit incentive to find low-cost ways to reduce greenhouse gas emissions, it is doubtful that carbon dioxide prices will rise high enough to dramatically increase agricultural production costs. If other major agricultural producers also face increasing production costs because their countries adopt carbon-reducing policies, then U.S. producers will not lose their competitive advantage. Furthermore, if production costs do rise significantly, and if most of the world's farmers face these higher production costs, then most, if not all, of the higher costs will soon be reflected in higher commodity prices that will compensate farmers for their higher costs.

Similarly, the benefits from providing carbon offsets to capped sectors of the economy will be modest as well. Benefits will accrue as more crop farmers will move to no-till farming, and a price for carbon will enhance the economics of methane recovery systems in livestock operations.

Given the likelihood of modest costs and benefits from a cap-and-trade system, perhaps agriculture should look at whether a cap-and-trade policy will change growing conditions for the better or worse as a deciding factor in whether to support a change in policy. Given how much irrigated agriculture in the West relies on consistent mountain snowfall and Corn Belt agriculture relies on warm summers with abundant rainfall, any disruptive change in climate will have a far greater impact on livelihoods than will the price of carbon. ◆

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Measuring Unmeasurable Land-Use Changes from Biofuels
Continued from page 6

like most economics models, are ripe ground for aggrieved parties.

As we look to agriculture and forestry as a means of offsetting carbon at low cost, the demand for economic models of land use will increase. If greater investment in data and knowledge of agriculture around the world occurs, then the precision with which these models can estimate the impact of biofuels on the quantity of land brought into production, where the land-use expansion will occur, what the land will be planted to, and how the new lands will be managed will only improve. ◆

Editor's Note

Researchers in the Center for Agricultural and Rural Development at Iowa State University have worked for the last 18 months with EPA staff and other academic modelers at Texas A&M University and Purdue University to estimate the impacts on agriculture from expanded biofuels. EPA staff then used the results of this analysis in their life cycle assessment of biofuels.

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