University of California, Berkeley
Department of Agricultural &
Resource Economics

CUDARE Working Papers

Year 2010 *Paper 1110*

Indirect Land Use Change: a second best solution to a first class problem

David Zilberman, Gal Hochman

and Deepak Rajagopal

Indirect Land Use Change: A second best solution to a first class problem

David Zilberman, Professor and Robinson Chair, Department of Agricultural and Resource Economics, University of California, Berkeley

Gal Hochman, Researcher, Department of Agricultural and Resource Economics, University of California, Berkeley

Deepak Rajagopal, Assistant Professor, Institute of the Environment, University of California, Los Angeles

ABSTRACT

Concern about the possible affects of biofuels on deforestation have led to assigning biofuel producers with the responsibility for greenhouse gas (GHG) emissions of the indirect land use changes (ILUC) associated with their activities when assessing their compliance with biofuel policies. We show that the computation of the ILUC is shrouded with uncertainty; they vary frequently, and are strongly affected by policy choices. It seems that its overall impact on GHGs is relatively minor. Once the ILUCs are introduced other indirect effects of biofuel may need to be considered which will increase the cost of biofuel regulations. Concentrating on direct regulation of biofuel and on efforts to reduce deforestation, wherever it occurs, may be more effective than debating and refining the ILUC.

1. Introduction

Concern about food security and independence, as well as mounting concern about climate change and the depletion of oil, led to policy initiatives that provided support to the production of various biofuels, including ethanol and biodiesel. Since policies are executed in a piecemeal fashion and different policies have different objectives, some of the policies that promoted biofuels had a fuel-security emphasis and others had an environmental emphasis. For example, the U.S. Energy Independence and Security Act of 2007 (Washington State University, Extension Energy Program, 2007) introduced biofuel subsidies and mandates in order to enhance fuel security but, to address environmental concerns, it set an upper bound (Renewable Fuel Standard, RFS) on greenhouse gas (GHG) emissions per gallon of biofuels (in particular, ethanol and biodeisel). Another set of policies that promote the introduction of biofuels is the Low Carbon Fuel Standard (LCFS) that requires that the GHG emissions per gallon of fuels will be a certain percentage below that of a baseline gasoline. The LCFS was introduced in California and has been considered in some European countries.

A common feature of these two policies is that the GHG emissions of biofuels are computed using lifecycle analysis (LCA) that takes into account the GHG emissions throughout the supply chain, including the production of fertilizers, shipping of gasoline from fields to plant, and conversion of feedstock into a fuel, such as corn into ethanol. Thus, more GHG emissions are attributed to biofuels that are produced with fertilizers that were generated using coal energy than those that were generated using natural gas. Furthermore, under the LCFS (and, in the future, most likely under the RFS) the GHG emissions attributed to biofuels includes the GHG emissions because of the indirect land-use change (ILUC) associated with the production of biofuels. The ILUC is the conversion of land from its current production (forestry) to agricultural production because of increases in food prices resulting from resource allocation to biofuels. The conversion from tropical forests to production of, say, soybeans, may result in significant emissions of GHG that may take years to recapture (Fargione et al. 2008). These concepts were introduced by

Searchinger et al. (2008) and reflect the concern that biofuel production will lead to deforestation that will generate extra GHG emissions that will then negate the reduction in GHG emissions resulting from the use of biofuels. This paper will argue that the use of the ILUC is misguided for conceptual, empirical, and political economic reasons.

2. Background

Biofuels around the world are used to fuel cars and to generate electricity. Historically, wood and animal waste were major sources of energy for power and cooking. Some of the early automobiles were fueled with ethanol but, with the availability and intensive use of fossil fuels, biofuels were delegated a secondary role in the transportation and the modern energy sectors. The energy crisis of 1974 saw the emergence of biofuel as a source of vehicular energy, but the decline of the energy prices during the 1980s and 1990s decimated that nascent biofuel industry. However, the use of ethanol alcohol as an oxygenating additive to fuels as a replacement for MTBE, combined with the rising energy costs in the early 2000s led to the reemergence of the biofuel industry that was incentivized by supportive legislation. Almost all of the biofuels currently produced are first-generation biofuels produced by a rather simple process that utilizes part of the mass of sugar, starch, and oilseed crops. The major crops are sugar cane and corn for ethanol, and soybeans, rapeseed, and palm oil for biodiesel. The GHG emission savings of first-generation biofuels compared to gasoline vary by crop and their supply chains. Sugarcane ethanol, for example, has relatively much lower direct (excluding ILUC) GHG emissions than corn ethanol. Sugarcane ethanol typically has around 60% less GHG emissions than baseline gasoline while corn ethanol has 10% to 30% less (Rajagopal and Zilberman 2007).

Contrary to the first-generation, the second-generation feedstocks provide an opportunity to use nearly the whole plant for biofuel production, not just parts of plants (grains, tubes, stalks), using advanced technologies that are able to convert cellulosic material into fuels (Rajagopal et al. 2009). Diverse feedstocks are considered at the research-and-development (R&D) stage, including agricultural crops and waste, fast-growing trees and forest residues, grasses (switchgrass and miscanthus), municipal solid waste, and wastes from pulp/paper processes. It is presumed that much of the production of second-generation biofuel can be done on "marginal" land. But these crops will compete with food crops for resources, and it is likely that at least some will have ILUC. Therefore, policies that consider the emissions resulting from ILUC as part of the overall GHG emission contribution of biofuel would also analyze the ILUC of second-generation biofuel.

A major reason why deforestation and land-use changes are the subject of much concern is that, although the primary source of the increased atmospheric concentration of carbon dioxide since the preindustrial period results from fossil-fuel use, land-use change is the second major contributor of GHG emissions (Intergovernmental Panel on Climate Change 2007). Land-use changes contribute to GHG emissions through the release of soil carbon as well as through the burning of trees, which releases the carbon stored within them.

The concerns from land-use change, coupled with the belief that the environment would be underpriced around the world, namely, that countries that possess tropical forests may undervalue the environmental amenities they provide, which would lead to expanded deforestation to increase food supply and lead policy makers in the United States and Europe to propose to expand the calculations of direct LCA and include ILUC (e.g., RFS, LCFS, European Directive). But is ILUC the right response?

3. Theory

The economic theory of agent's behavior, as well as public economics, can provide a theoretical background to assess the use of ILUC. As Rajagopal et al. (2007) suggest, the introduction of biofuel increased the demand for agricultural crops like corn and soybean and thus may result in increased demand for land. But, at the same time, it may also increase the gain from investment in intensification of agricultural production and adoption of new technologies. The effect of the introduction of biofuel or expansion of biofuel production on land use is an empirical problem and depends on the magnitude of land-use expansion in response to higher food prices compared to the intensification and technology-adoption effects. Even when the demand for land use is expanded, the actual acreage in agricultural production may not change much if policies are enacted to increase the value of preserving land in conservation activities. The extent of the ILUC effect is not only affected by increased demand for land but also by the extent that preservation of wildlands is protected by policies or incentives.

Economic theory suggests that unregulated competitive markets sub-optimally manage GHG emissions as well as land use since the technical externalities associated with these activities are not taken into account in making allocation decisions in these markets. Technical externalities are unintended physical outcomes of choices of economic agents. Burning fuels emits GHG emissions that contribute to global warming, which is a "public bad." Deforestation is causing both emission of GHG, which is a global externality, as well as loss of wilderness and biodiversity, which are another sort of technical externality. The way to address technical-externality problems is to introduce policies that will make decision makers consider the social cost of the externalities that they generate. These policies include incentives, such as carbon taxes, tradable-permit schemes, direct control (zoning activities), or even subsidies and policies, such as payment for environmental services (PES) (Bulte et al. 2008). An efficient policy to address GHG emissions and land-use changes may consist of a uniform global price for carbon, equal to the marginal social cost of the contribution of carbon to climate change as well as pricing of land-use changes reflecting the value of the environmental amenities affected by these changes (Hochman et al. 2010).

When policy makers encounter difficulty in assessing the social cost of technical externalities like GHG emissions, Baumol and Oates (1971) recommended the use of cost effective policies, these policies are designed to achieve a predetermined pollution-reduction target at the lowest cost. These policies may also result in GHG pricing. But the price represents the opportunity cost imposed by the GHG emission constraint, and it may be implemented through policies mentioned above, including carbon taxation or cap-and-trade schemes. The Kyoto Protocol followed the spirit of Baumol and Oates by establishing targets for GHG emissions and encouraging the use of financial incentives to achieve them. But, this policy wasn't cost effective in the sense that not all countries participated in the program, carbon pricing wasn't uniform and didn't apply to all carbon emitting activities, etc.

The introduction of environmental policies may affect market prices and that in turn may impact the environment. The economic literature introduced the notion of pecuniary externalities, namely, the changes in the behavior of economic agents may affect the other agents through market forces by affecting prices. The ILUC is triggered by a pecuniary externality, namely, increases in the price of agricultural commodities, such as corn, soybeans, and sugarcane resulting from the introduction or expansion of biofuel, that may lead to technical externalities, more GHG emissions.

The existence of pecuniary externalities (e.g, lower supply of food in response to weather conditions leading to higher prices) in the case of competitive industries is a normal part of market performance and is not a source of inefficiency that requires government intervention. It is clear, however, that the direct technical externalities of biofuel producers should be regulated. Yet, it seems that the ILUC should not be regulated since the ILUC originated from pecuniary externalities of the biofuel sector, which consists of competitive producers- each to small to affect market outcomes. However, the biofuel production activities we consider are tied to government policies (LCFS, RFS), and these policies are of sufficient scale to affect market prices, and these effects have to be considered in the policy design. Indeed, Stavins and Jaffe (1990) argue that environmental polices should take into account the changes in industry's choices, the associated changes in prices and the resulting technical externalities they may cause. An optimal carbon tax should be calculated based on the expected economic reality after the introduction of the taxes, and will apply to all pollution. Wu, Zilberman, and Babcock (2001) suggest that the design of PES programs that pay landowners for not farming should compensate landowners that may not be operating before the program is introduced, but are likely to operate as a result of rising food prices.

Thus, when all pollution is subject to a first best or cost effective policies, polluters should not be accountable for pollution generated as a result of their pecuniary externalities (Hochman et-al 2010). However, when pollution control regulations apply only to a subgroup of polluters, the policies should be adjusted to account for pollution generated by others as results of the pecuniary externalities of the regulated population. This line of argumentation makes the case for incorporating ILUC as part of partial biofuel regulations- like RFS and LCFS. But other factors have to be taken into account when considering the use of ILUC in biofuel policies.

A major guiding principle of policy design is consistency. If one type of indirect effect of biofuel is considered, then all significant indirect effects should be considered. The work by Rajagopal, Hochman, and Zilberman (forthcoming) introduces the concept of indirect fuel-use change (IFUC). Increase in ethanol production may reduce the price of oil and may reduce the incentive to invest in some of the more expensive and more polluting sources of fuel, e.g., fuel from deep ocean wells or from tar sands. Conversely, the lower price of oil attributed to the introduction of biofuels may also lead to more drilling, and that may result in extra GHG emissions. These changes triggered by prices can be quite substantial and, if we consider ILUC, we should consider the IFUC. Another indirect effect of the introduction of biofuels on GHG emissions is the change in the use of by-products in oil refining. The refining process that produces gasoline and diesels also produces other by-products that may be used for heating and other activities and emit a significant amount of GHGs. The reduction in the use of gasoline and diesel because of the introduction of biofuel will reduce the production of these oil by-products and the net effect on GHG depends upon what they will be replaced with and how. Other examples of indirect effects include the effect of energy prices on fertilizer use and productivity that may affect GHG emissions through its impact on crop production. Furthermore, if we are consistent with our application of the concept of ILUC, it should be applied not only to biofuel regulations but to other policy regulations as well. It should be applied to assess policies, such as the Conservation Reserve Program (CRP), taking land out of agricultural production so that it will be part of the CRP, may increase prices, and lead to deforestation in Brazil so that one might consider, to be consistent, the environmental gains of the CRP versus the environmental cost from the deforestation in Brazil.

The ILUC also raises issues of accountability and transparency. Standard environmental economic analysis suggests that polluters are accountable for the activities that they generate. One advantage of policies such as taxes or even direct control that are based on polluter direct action is their transparency that enhances their political acceptability (Barde 1994). Biofuel policies are based on LCA because it enables accounting for GHG emissions of segments of the supply chain that are in countries that don't regulate GHGs by charging the seller of the biofuel for the GHG emissions of the entire supply chain and assumes that the cost will be transmitted throughout the chain[1]. ILUC goes even further than LCA; while theoretically justifiable as second best policy they, it makes the seller of biofuel indirectly responsible for activities of agents that are affected by the seller's choices through the vagaries of market forces and related government policies. As we show later, the ILUCs are unstable and vary over time, and thus not very transparent.

Another consideration in the design of policy is transaction costs. As we will show below the estimation of ILUC is not simple- they are unstable and are policy dependent. Other categories of indirect costs will be costly to compute as well.

---

[1] The gain from accounting for the GHG emissions of the entire supply chain by using LCA has to be larger than the possible cost of "gaming the system" ("shuffling", Yeh and Sperling 2010)

These costs consist not only of the direct computation costs but also of time cost of delayed decision making and implementation of project. While delayed decisions may be required to provide extra knowledge, especially in cases of irreversibility, (Arrow and Fisher 1974) "time is money" and excessive delay is inefficient. The expected gains from incorporation of ILUC need to exceed the extra costs to justify their inclusion as part of biofuel polices.

The impact of including ILUC in the policy process cannot be judged solely by theoretical argument. The assessment of empirical importance of ILUC is crucial in determining its relevance and value.

4. Quantifying ILUC

Empirical studies suggest that quantification of ILUC is quite difficult because it has been very unstable over time and sometimes even varying in sign. Furthermore, the impact of commodity price increases on deforestation hasn't been very well documented.

Searchinger (2008) presented an important study arguing that ILUCs of biofuels are very substantial. However, in another study, using different data and modeling approaches, Hertel et al. (2010) found the ILUC coefficient to be one-third of that predicted by Searchinger (2008) and Tyner (2010) found this ILUC to be even smaller. These differences are partially because of differences in methods, assumptions, and data, but they also show that ILUCs are very volatile and change over time.

One indicator of the ILUC is an elasticity, $\varepsilon_{L/Q} = \frac{\Delta L / L}{\Delta Q / Q}$, that denotes the relative change in agricultural acreage, $\Delta L / L$, in response to relative change in agricultural supply, $\Delta Q / Q$. These elasticities vary significantly over crops and time. Rajagopal, Hochman, and Zilberman (2010) computed the elasticity for six crops as well as aggregate grain crops for six periods of time between 1960 through 2007. In the case of wheat, the elasticity varied from -.06 (which represents reduction in acreage in response to increased output) to .20 (which represents an increase in acreage in response to increased supply). In the case of corn, the elasticity varies from -.08 to .45. These differences in elasticities may reflect that, in certain periods, there have been high rates of technological innovation (e.g., the adoption of Green Revolution varieties) that might have contributed to increased output and reduced acreage, resulting in a negative elasticity. In other cases, technological change might have been slow and expansion of agricultural production was in an area that was not highly productive. So the net effect is that the elasticity is quite high. Altogether, the average elasticity of acreage with respect to changes in supply is quite low (.16), which is half of what Searchinger (2008) suggested, but greater than what was estimated by Hertel et al. (2010).

The large fluctuations of the elasticities are indicators that ILUC coefficients are very volatile, which suggests that policies that use them have to change their parameters frequently. Further analysis suggests that, in many cases, agricultural acres measured in agricultural statistics may be greater than the actual area farmed because of double and triple cropping. In periods where there has been a significant increase in the amount of acres double cropped, the measures of ILUC that are based on crop acreage will suggest that it is quite significant while, in reality, the total farmed land has not changed much.

Historically, increases in agricultural commodity prices have tended to be followed by a high rate of technological innovation (Cochrane 1993) that might have been followed by decreased acreage. For example, in the case of the United States, agricultural farming reached its highest level of acreage at the end of the First World War and has been declining ever since. Furthermore, output productivity has increased tenfold since then (Federico 2009). A study of the economic history of food production suggests that world agricultural production more than tripled between 1950 and 2000 while acreage in arable land and tree crops grew by less than 25%. Mundlak's (forthcoming) assessment of changes in agricultural productivity has documented that, over the last 100 years, the drastic increase in