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Indirect Land Use Change: A Second-best Solution to a First-class Problem

David Zilberman and Gal Hochman
University of California, Berkeley

Deepak Rajagopal
University of California, Los Angeles

Concern about the possible effects of biofuels on deforestation have led to assigning biofuel producers with the responsibility for the 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. If ILUC is introduced, other indirect effects of biofuel may need to be considered, which will increase the cost of biofuel regulations. Concentrating on direct impacts of biofuel policies on eliminating distorted incentives for biofuel production and on efforts to reduce deforestation—wherever it occurs—may be more effective than debating and refining the ILUC.

Key words: indirect land use, biofuel, greenhouse gases, Low Carbon Fuel Standards.

Introduction

The introduction of biofuel policies in the United States was justified by concern for both food security and climate change.[1] To address the former, the US Energy Independence and Security Act of 2007 (Washington State University, Extension Energy Program, 2010) introduced biofuel mandates and subsidies; to address the latter, the same act 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), which 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 the RFS and LCFS is that the GHG emissions of biofuels are computed using lifecycle analysis (LCA), which 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 grown 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. ILUC is the conversion of land from its current production (say, forestry) to crop production in response to the increases in food prices, which have resulted from the diversion of cropland to produce 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, Hill, Tilman, Polasky, & Hawthorne, 2008). The notion of ILUC was introduced by Searchinger et al. (2008) and reflects the concern that biofuel production will lead to deforestation, which will generate extra GHG emissions that will then negate the reduction in GHG emissions resulting from the use of biofuels. This article will argue that the inclusion of the ILUC in computing LCA for biofuel policies is misguided for conceptual, empirical, and political economic reasons.

Background

Biofuels are used around the world to fuel cars and to generate electricity. Historically, both 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 modern energy sectors. The energy crises of the 1970s 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 methyl tertiary butyl ether (MTBE),

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[1] *Political economic considerations, including pressure from the farm lobby, also played a role in establishing biofuel subsidies (see Koplow and Dernbach [2001]).*

combined with the rising energy costs in the early 2000s, led to the reemergence of the biofuel industry, which was incentivized by supportive legislation (de Gorter & Just, 2009). 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 crops. 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 10-30% less (Rajagopal & Zilberman, 2007).

Despite the GHG emission savings from first-generation feedstocks, concerns about their environmental and food-security implications (Pimentel et al., 2009) led to the increased emphasis on development of second-generation feedstocks (Rajagopal, Sexton, Roland-Holst, & 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)—by using advanced technologies that are able to convert cellulosic material into fuels (Rajagopal, Sexton, Hochman, & Zilberman, 2009). Diverse feedstocks are undergoing research-and-development (R&D) activities, including agricultural crops and waste, fast-growing trees and forest residues, grasses (switch grass and miscanthus), municipal solid waste, and wastes from pulp/paper processes. While there are not yet commercial plants producing ethanol from cellulosic material, it is presumed that much of the production of second-generation biofuel feedstock production 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 biofuels would also analyze the ILUC of second-generation biofuels.

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 about land-use changes—coupled with the belief that countries that possess tropical forests may undervalue the environmental amenities they provide—has policymakers in the United States and Europe concerned that failure to include ILUC in LCA calculations would lead to expanded deforestation and increased GHG emissions. But is the inclusion of ILUC in emission calculations the right response?

Theory

The economic theory of agents’ 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 biofuels 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 wild lands is protected by policies or incentives.

Economic theory suggests that unregulated competitive markets sub-optimally manage GHG emissions and 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 GHGs (which is a global externality) as well as loss of wilderness and biodiversity (which is 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 payment for environmental services (PES; Bulte, Lipper, Stringer, & Zilberman, 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, Sexton, & Zilberman, 2010).

When policymakers encounter difficulty in assessing the social cost of technical externalities like GHG emissions, Baumol and Oates (1971) recommended the use of cost-effective policies that are designed to achieve a predetermined pollution-reduction target at the lowest cost. These policies may also result in GHG pricing. This 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 (1971) by establishing targets for GHG emissions and encouraging the use of financial incentives to achieve them. But, this policy is not 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.

In addition to introducing the notion of technical externalities, the economic literature introduced the notion of pecuniary externalities, namely, the changes in the behavior of economic agents may affect other agents through market forces by affecting prices. The ILUC is triggered by pecuniary externalities, namely, increases in the prices of agricultural commodities (such as corn, soybeans, and sugarcane) resulting from the introduction or expansion of biofuels. These pecuniary externalities may lead to technical externalities and more GHG emissions resulting from increased crop acreage.

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 ILUC should not be regulated since it originated from pecuniary externalities of the biofuel sector, which consists of competitive producers—each too small to affect market outcomes. However, the biofuel production activities we consider are tied to government policies (LCFS, RFS); 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 policies 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 pollution is subject to 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 inclusion 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 (2011) introduces the concept of indirect fuel-use change (IFUC). Increases 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 tar sands. Conversely, the lower price of oil attributed to the introduction of biofuels may also lead to more driving, 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 byproducts in oil refining. The refining process that produces gasoline and diesel also produces other byproducts 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 biofuels will reduce the production of these oil byproducts, 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), which is diverting land out of crop production) and to conservation activities. These diversions may increase crop prices and lead to deforestation in Brazil. Thus, to be consistent, assessment of the CRP should consider the environmental gains of the CRP versus the environmental cost from the deforestation in Brazil.

The inclusion of ILUC in biofuel policies also raises issues of accountability. 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 polluters' direct action is their transparency, which 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 do not 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.[2] Accounting for ILUC goes even further than just LCA; while theoretically justifiable as second-best policy, accounting for ILUC in biofuel policies 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 all over the world.

Another consideration in the design of policy is transaction costs. As we will show below, the estimation of ILUC is not simple—it is unstable and policy dependent. Other categories of indirect costs will be costly to compute as well. These costs consist not only of the direct computation costs but also of time cost of delayed decision-making and implementation of a project. While delayed decisions may be required to provide extra knowledge—especially in cases of irreversibility (Arrow & 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 policies.

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.

Quantifying ILUC

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

Searchinger et al. (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 et al. (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, $\varepsilon_{L/Q} = (\Delta L/L) / (\Delta Q/Q)$, 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. Zilberman, Hochman, and Rajagopal (forthcoming) 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 -0.06 (which represents reduction in acreage in response to increased output) to 0.20 (which represents an increase in acreage in response to increased supply). In the case of corn, the elasticity varies from -0.08 to 0.45. 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 regions that were 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 (0.16), which is half of what Searchinger et al. (2008) suggested, but greater than what was estimated by Hertel et al. (2010).

The large fluctuations of the elasticities over time are indicators that ILUC coefficients are very volatile, which suggests that policies that use them have to change their parameters frequently. Further analysis

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[2] *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 & Sperling, 2010).*

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 was frequently 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 (2011) assessment of changes in agricultural productivity has documented that, over the last 100 years, the drastic increase in agricultural productivity was mostly associated with increased intensification, including fertilizer, pesticides, irrigation, and capital, which substituted for land without much change in acreage. Looking toward the future, Miranowski, Rosburg, and Aukayanagul (2010) used historical trends as well as predictions of experts from life-science companies to predict yield dynamics in corn. They suggest that, in the next 20 years, corn yield is likely to increase significantly and much of the increase in food and projected biofuel demand can be met without expansion of current acreage.

As mentioned earlier, intensification is one response to increased demand for agricultural products, and it may have different forms. Productivity may be increased by increased use of chemicals and water, as well as adoption of improved varieties. However, decreasing marginal productivity of energy inputs of agriculture and the increased cost of these inputs may limit the extent of increasing productivity from increased energy input use. The increase in commodity prices during the Russian Wheat Deal, 1973-1975, led to increased investment in agricultural inputs that resulted in periods of excess supply in the 1980s. Similar developments have been documented elsewhere. Thus, the cyclical behavior of agricultural productivity may result in a high degree of variability of measures of ILUC.

Alston, Beddow, and Pardey (2009) argue that investment in agricultural research has been a major cause of increased agricultural productivity. But investment in research varies across locations, and returns to this investment vary over space and time. The reason for some of the differences is the inherent heterogeneity of agricultural systems, as well as differences that may result in different patterns of land use, R&D activities, and changes in productivity. Furthermore, even when technologies are available, their adoption is time-consuming and may take years to materialize (Feder, Just, & Zilberman, 1985). Adoption of modern technologies is highly affected by changes in prices. High rates of adoption occur when either output prices increase or when input prices are rising and the incentive to introduce substitution is growing. The volatility of agricultural commodity prices as well as agricultural inputs (such as fuel) translates to significant variability in adoption rates and results in instability of changes in productivity and instability in indicators of ILUC.

Changes in land use are also affected by policies. For example, Zilberman, Schmitz, Casterline, Lichtenberg, and Siebert (1991) found that policies that excessively restrict the use of pesticides are likely to strongly enhance agricultural land use.[3] Therefore, changes in pesticide regulations or other regulations on input use or input pricing may strongly affect agricultural land use. Regulations (e.g., the regulation that banned the use of agricultural biotechnology) may also constrain agricultural productivity. Changes in regulation that, for example, would enable the use of genetically modified varieties in Asia, Europe, and Africa are likely to increase agricultural productivity without much change in land use (Sexton, Zilberman, Rajagopal, & Hochman, 2009). Thus, the magnitude of the ILUC effect may be strongly affected by agricultural policies and may be modified with changes in policies governing agricultural production.

High food prices lead to adoption of improved technologies and increased acreage. In some cases, expansion of agricultural land may lead to reduction in soil carbon. For example, farming with low- and no-tillage (as well as other) practices may lead to significant sequestration of carbon (Lal, 2004). In recent years, the increased adoption of herbicide-resistant varieties enabled the introduction of low-tillage practices, which

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3. *There is a possibility to reduce pesticide use with minimal or no impact on productivity by improving pesticide policies.*

led to sequestration of carbon (National Research Council, 2010).

The inclusion of ILUC in LCA calculations used for biofuel regulation was predicated on a presumed link between an increase in commodity prices and deforestation. It was hypothesized that higher commodity prices would lead to increased acreage of cropland, and this land would be obtained by clearing forests, which would result in the release of carbon that had been sequestered by the trees and the land. The recent work of DeFries, Rudel, Uriarte, and Hanse (2010) correlates deforestation with increases in commodity prices between 2001 and 2005. The study by Hausman Almirall (2009) shows that soybean acreage in Brazil is responsive to soybean prices and that much of the increase in acreage is in the Cerrado (savanna in Brazil). However, the process of deforestation is quite complex and there have not been very many studies that clearly link high-commodity prices to deforestation. A recent presentation by Guilhoto and Ichihara (2010) suggests that land-use changes in Brazil are sequential. Most of the deforestation occurs in frontier lands where forests are converted primarily to extensively used rangeland. Some of the production of soybean is a result of conversion of rangeland to farming (where the overall share of soybean is relatively small). Significant expansion in soybean and sugarcane production did not occur in these frontier lands. In some cases, the conversion of savannah or marginal lands to production of soybean—especially with no tillage practices—actually leads to sequestration of carbon and reduces GHG emissions (Lal, 2004).

The pattern, where wildlands and forests are first converted for extensive activities and intensification occurs later, is consistent with the historical analysis of Cochrane (1993) and the conceptual model of Hochman and Zilberman (1986). Governments in the past have encouraged deforestation as part of a development policy by introducing homestead policies as well as building infrastructure and subsidizing production. Guilhoto and Ichihara (2010) suggest that this was the case in Brazil. But government policies can also slow and reverse deforestation through the introduction and enforcement of zoning and incentives, even in the case of Brazil (Fearnside, 2003; Hochstetler & Keck, 2008). Furthermore, the extent of deforestation can be affected by international agreement, including PES that can be used to protect forest services. Since policies for management of tropical forests and other natural resources are evolving, they add another dimension of instability to studies that measure and predict ILUC. The econometric analysis by da Silva and Goncalves (2009) of deforestation in the Brazilian Amazon in the 2000s finds that it was positively related to meat prices and soybean prices (lower impact), but negatively related to enforcement of environmental laws by Brazilian government agencies. An article in The Economist magazine suggests that the rate of clearance of tropical forests in Brazil has been decreasing since 2006 (which is supported by FAOSTAT data [FAOSTAT, n.d.]), and some of this has been attributed to government action. While imperfect, the Brazilian government made a GHG-cutting commitment (39% of projected emission by 2020 and 40% of this reduction comes from avoidable deforestation; The Economist, 2010).

Political Economic and Dynamic Considerations

The LCFS and the RFS were developed in response to the lack of a coherent energy policy. They partially present attempts to reduce GHGs in the energy sector. But, as we evaluate these policies, and in particular the inclusion of ILUC in LCAs, we have to consider what is being gained and what are the costs of these policies. The empirical studies suggest that the ILUC of biofuels are highly uncertain (estimates vary significantly over studies), unstable (in the sense that the ILUC coefficients change significantly over time), and are frequently low. Thus, policies that aim to reduce biofuel acreage may not yield strong gains in terms of GHG emissions. At the same time, these policies expand uncertainty faced by investors and increase the cost of regulation, which may slow the introduction of innovations.

Once we introduce the concept of indirect effects to biofuels, then it may, for consistancy, need to spread to other regulatory areas, and incorporation of indirect effects into policy design will become part of the policy process. Incorporating indirect effects is part of a second-best policy and we should aspire to first-best policies. In addition, the introduction of indirect effects of various types will increase the cost of policymaking. Our analysis of the case of biofuel demonstrates the difficulty inherent in defining and computing indirect effects. If such effects were computed for most policies, it would lead to high transaction costs because of the difficulty of computing. Furthermore, if indirect use becomes integrated into most policy designs, it will lead to multiple regulations of the same activities. Polluting activities will be regulated both directly and indirectly, and that will increase the cost of regulation and may lead to inefficiencies.

The uncertainty associated with the parameters of ILUC (and other indirect effects) in biofuel policies is also likely to deter innovation. The literature on innovations, especially the real-option approach of Dixit and Pindyck (1995), recognizes that uncertainty about future conditions and policies is a key factor in reducing investment in new technologies. The consideration of ILUC in biofuel regulatory policies increases the uncertainty regarding benefits and costs considered by firms as they assess biofuel projects. This increased uncertainty may lead to reduced investment in new biofuel technologies.

One way to reduce concern about variability and yet improve environmental quality over time is that the regulatory parameters, such as an RFS upper bound, will become stricter over time, which is not the case for GHG upper bounds under RFS. Since biofuels—especially second-generation biofuels—are young industries, learning by doing will reduce costs (including environmental costs) in this industry (Feder & Schmitz, 1976). Even in the case of corn biofuel, there is some evidence that emissions have declined between 2002 and 2010 (Liska et al., 2009).

The ILUC was introduced into LCA calculation of biofuels to compensate for the presumed lack of regulation of land use in developing countries. To some extent, it represents an unwarranted paternalistic outlook. Historically, however, the US track record when it comes to land-use regulation is not sterling. Indeed, after eliminating much of the forests of the United States, conservation policies and institutions were introduced leading to aforestation and the reemergence of forests (Hamburg, 2010). Instead of assuming that developing countries will continue to mismanage tropical forests and cannot control deforestation, it may be better to assist in the development of strategies for sustaining tropical forests and protecting biodiversity. Such intervention may be in the form of PES. With such intervention, the case for inclusion of ILUC in LCAs will be weakened. As The Economist article suggests, Brazil has intensified its enforcement of policies to control deforestation in recent years, which contributed to the reduction in their rate of deforestation. The enactment and implementation of such policies can be affected by pressure and other incentives that the United States and the rest of the world may provide. Instead of trying to sterilize the impact of deforestation that is assumed to be associated with biofuel activities in the United States, it may be worthwhile to provide a "carrot-on-stick" approach to reduce deforestation directly.

We are aware that the negotiations on climate-change agreements are stalling, but the US government and private individuals can affect GHG emissions in developing countries by either initiating PES to preserve certain areas of unique ecological value or by introducing sanctions against the sale of products that were not certified to meet responsible environmental stewardship behavior. While these policies have significant limitations,[4] they provide signals that may lead to desirable changes in behavior.

Climate policy is in its infancy. While political realities constrain policy choices, policymakers have to aspire to design policies that are transparent and effective; policies that are close to first-best rather than permanently subpar. The incorporation of ILUC in LCA of biofuels is a policy choice that aims to control deforestation in Brazil by affecting choices in Kansas and California. 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 impacts of biofuel policies on eliminating distorted incentives for biofuel production and on efforts to reduce deforestation, wherever it occurs, may be more effective than debating and refining the ILUC.

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[4] For example, if sanctions are voluntary or not global, products that are produced in an "environmentally irresponsible" manner can be sold in areas where the sanctions do not hold.

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