Biofuel development was partially motivated by the promise of greenhouse-gas (GHG) emissions savings. A high-profile article by Searchinger et al. (2008), however, argued that biofuels are likely to increase GHG emissions relative to the fossil fuels they were intended to replace because of emissions attributable to ‘indirect land use change’ (ILUC). Biofuel production tends to reduce the supply of corn or other feedstocks available for feed or food, leading to higher prices. Farmers respond to higher prices by increasing corn supply, which expands the footprint of farming into natural land. To conclude that biofuels increase GHG emissions on net, Searchinger et al. (2008) applied a very popular model of the agricultural economy that relies on numerous assumptions. This editorial explains how subsequent more detailed analyses have shown this work to be seriously flawed and misleading.

Searchinger et al. (2008) has had an immense impact on the development of biofuels, raising skepticism about the environmental benefits of corn ethanol and other biofuels. Government agencies\(^1\) took notice, incorporating ILUC effects into decisions about biofuel policy. Because Searchinger et al. (2008) made headlines, scientists have closely examined their conclusions and found some of their assumptions to be extreme. For example, Khanna & Crago’s (2012) survey reports that the Searchinger et al.’s (2008) original computations of the ILUC GHG effect (104 gCO\(_2\) MJ\(^{-1}\) for corn ethanol) was much higher than the findings of other studies, including those of Hertel et al. (2010) (27 gCO\(_2\) MJ\(^{-1}\)), the US EPA, and the California Air Resources Board.\(^2\) Tyner et al. (2010) calculated the ILUC emissions to be as little as one-eighth the size asserted by Searchinger et al. (2008).

There are many reasons for the wide variation in these conclusions, including different estimates of model parameters, such as supply and demand elasticities, different functional forms, the incorporation or exclusion of emission credits for coproducts, such as dried distillery grain stocks, and assumptions about the efficiency of biofuel refining and productivity of agricultural production. Recent studies have suggested that ILUC coefficients are inherently uncertain, and therefore, methods have been developed to better address these uncertainties (Rajagopal & Plevin, 2013).

The Searchinger et al. (2008) results may now be seen as fundamentally flawed not just because the ILUC is uncertain and estimates vary considerably, but also because it fails to capture the basic features of agricultural industries and land resources.

First, the ILUC analyses of Searchinger et al. (2008) relied on static models whereas the agricultural industry is dynamic and uncertain. Major studies of the history of American agriculture, as depicted by Cochrane (1979) and Schultz (1964), documented that periods of high prices lead to investments in capital goods and investments in new technologies that tend to increase productivity per unit of land.\(^3\) Unless there are heavy restrictions on new technologies, one long-run effect of increasing prices may be new innovations that bring prices back down. Indeed, seven years after the peak prices in 2008, agricultural commodity prices are now quite low (the price of corn declined from around $300/ton in 2008 to around $170/ton in 2014). Furthermore, Long et al. (2015) concluded that the increase in production, since the introduction of corn ethanol, has more than covered the amount diverted into ethanol. Therefore, much of Searchinger et al.’s (2008) ILUC estimates do not capture the current reality, reflecting instead the conditions they observed in 2008. A recent article by Dumortier et al. (2011) showed that by employing the same model of Searchinger et al. (2008), but with more

\(^{1}\)Examples include the California Air Resources Board, US Environmental Protection Agency (EPA) and European Union.

\(^{2}\)Both the US EPA and California Air Resources Board found the GHG effect from ILUC to be less than one-third as high as Searchinger et al.’s (2008) estimates.

\(^{3}\)This is consistent with new thinking in capital theory (Dixit & Pindyck, 1994) that technological change and investment occurs once prices cross a critical threshold.

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realistic assumptions, altered ILUC emission estimates by a significant order of magnitude. As the subsequent literature found, Searchinger et al.’s (2008) results are extreme outliers.4

Second, most models of ILUC erroneously assume that increased agricultural crop land is directly linked to deforestation and other conversions of wildlands to farmland. Yet, these assumptions are not consistent with theoretical and, most importantly, empirical studies based on history. Wildlands are finite resources of varying qualities, and both conceptual and historical analyses have suggested that their conversion frequently occurred unrelated to and prior to the introduction of crop production and in many cases are caused by institutional failures. Economic models of land conversion5 argue that a socially optimal conversion of wildlands at each period should occur when the marginal benefits from conversion (wood, food production, etc.) are equal to the social marginal cost of conversion. The marginal cost of conversion includes the physical cost and the social cost for present and future generations. Private actors may not consider the social cost of conversion, and thus, achieving optimal wildland management requires government intervention that takes into account the cost to the public. Furthermore, deforestation occurred initially to provide wood for energy and construction and then led to the expansion of pastureland and finally to crop production. Southgate (1990) suggests that weak property rights accelerated deforestation because conversion was not constrained by regulations or people were not assured ownership that would induce them to intensify farming of converted land. A subsequent study confirms (Southgate et al., 1991) that forces like population growth and highway construction are associated with deforestation. Still, the literature suggests that over time, the deforestation process may slow, the settlement process may end, and the agricultural cropland base of societies may stabilize. These dynamic models also suggest that deforestation processes are more likely to occur early on in the agricultural expansion process but are likely to slow in older civilizations that may have depleted agricultural land. Indeed, Fig. 1 supports this theory. Agricultural acreage of the newly developing world continues to grow as these countries and populations are growing. This analysis has implications for the indirect land use effect. Deforestation processes are more likely to occur in developing countries, especially in areas where forest conservation is not emphasized.

A broader historical perspective on agricultural land (Goldewijk & Ramankutty, 2004) shows that global agricultural cropland has grown nearly fivefold (2.7–14.7 million Ha) and pastureland nearly sixfold (5.2–31.0 million Ha) since 1700. In the early period, much of deforestation was due to biomass harvest for fire, but over time, forestland conversion was largely to make way for farming. Recently, however, forests have been cleared to make room for pasture and rangeland, which were later converted to cropland.

Sometimes, the individuals responsible for deforestation and those who convert land to cropland are not the same. Brazil offers a prime example of this process. According to IBGE (2011), of 329.9 million total arable Ha in Brazil, only 59.8 million is cropland, 158.7 million is in pastureland, and 137.2 million remains undeveloped. Much of the 295.9 million Ha of land either in pastureland or that is available was converted from forestland or native vegetation and has not been converted for agricultural production. In the case of Brazil, the government encouraged development of large pig iron production facilities in the Amazon, which contributed to large levels of deforestation (Fearnside, 1989).

In recent years, however, the Brazilian government began prioritizing the protection of forests. As a result, deforestation slowed around the same time that prices of biofuel, corn, and soybeans soared. This suggests that an effective way to reduce deforestation is to make it a policy priority. The recent case of Brazil suggests limited correlation between expansion of

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4The analysis of Dumortier et al. (2011) also suggests that strategies that pursue investment in research and development and enhancing supply tend, in the long run, to reduce the GHG effect of biofuel and similar policies.

5See Hochman & Zilberman (1986), Southgate (1990), Southgate et al. (1991), and Zilberman et al. (forthcoming).
agricultural production and deforestation in developing economies. The correlation is lower still in developed countries.

These empirical observations are further supported by historical modeling and econometric estimation. For example, between 1960 and 2000, grain harvest doubled while cropland use only increased by 12% (Foley et al., 2005). Most of the dramatic increase in output is due to increased productivity, which was achieved by public and private investment in research. The introduction of genetically modified organisms (GMO) de facto reduced the footprint of agriculture by increasing yields.6 Swinton et al. (2011) suggested that cropland expansion for biofuel in the United States is limited and that most of the agricultural land base has already been converted to farming. In other words, even significant increases in commodity prices will result in nominal, if any, agricultural land expansion.

Two of the greatest agricultural economists of the 20th century, Galbraith & Black (1938) made the case that while price variation may be significant in farmers’ decisions about what to plant, the overall acreage in agricultural production is quite insensitive to prices in a mature economy, such as the United States. A recent study by Barr et al. (2011) found that the elasticity of land use in the United States with respect to agricultural prices is 0.03, which confirms Galbraith & Black’s insight. However, the same study found that while the elasticity of cropland in Brazil in the 1990s was significant (0.2), it stabilized around 0.05 after 2000 even as commodity prices soared. This suggests again that the key element in slowing deforestation is a government’s will to enforce protectionist policies. Even when conversion does occur, it is mostly conversion of rangeland and not forest.7

At the end of the day, policymakers seek factors that are transparent, stable, and coherent. Of course, this is essential for rallying political support, but when policy is set and evaluated according to parameters that are uncertain and vague, it has the potential to deter further innovation and development of technologies that can have significant economic and environmental benefits. The different biofuels promoted in recent years have limitations to be sure, but the relative benefits of their GHG emission reductions can be easily measured and captured by the direct effects of biofuel.

6Regulation restricting adoption of GMOs in Europe and Africa actually prevented further reductions in GHG emissions, constraining the agricultural footprint of agriculture (Barrows et al., 2014).

7Indeed, these were two major sources of increases in supply in Latin America. Intensification occurred due to adoption of genetically modified varieties as well as switching to double cropping (Barrows et al., 2014).

Searchinger et al.’s (2008) article was not written ‘in vain.’ It turned our attention to real concerns associated with biofuels: increasing rates of deforestation and GHG emissions due to land use changes. Yet closer examination of their initial study has raised some grave concerns, and in light of more recent results, we must cast doubt on their original estimations. The biofuel sector is in its infancy, and if it is to be a contributor to economic growth and environmental sustainability, it needs to continue to learn and improve its productivity (Hettenga et al., 2009). Investment and growth of the industry should not be curtailed by ‘much ado’ about what seems to be, upon close scrutiny, very little. Furthermore, the inclusion of ILUC in regulation does not ensure that emissions would absolutely decline when fuel market effects are considered (Rajagopal & Plevin, 2013).8

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8One of the main implications associated with the introduction of indirect land use is that once one indirect effect is introduced to the regulatory process, others need to be considered. For example, the indirect fuel use effect (Rajagopal et al., 2011) as well as the indirect effects associated with OPEC and byproducts (Zilberman et al., 2013). Assessing all of these effects will further add to the regulatory costs.
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