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Market-mediated environmental impacts of biofuels ☆

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ABSTRACT

This paper surveys the evidence on market-mediated environmental impacts of biofuels, with special attention to the indirect greenhouse gas emissions stemming from land cover change in the wake of increased demand for biofuel feedstocks. We find clear evidence that market mediated land use response to crop price changes has occurred over the past decade. However, despite all the research that has been done and all the advances made, there remains considerable quantitative uncertainty surrounding biofuels induced land use change. Obtaining precise estimates of these impacts is likely beyond the reach of current models and data.

1. Background and policy context

The global leaders in biofuel production have been the US, Brazil, and the European Union (EU) (Tyner, 2008). In all three regions, the initial policies used to stimulate biofuels were government subsidies. However, over time as the level of biofuels production grew, and the burden of the subsidy on government budgets increased, all three regions moved towards mandates or targets, which shift the cost of the policies towards consumers of the biofuels. The major biofuel in the US and Brazil is ethanol, and in the EU, it is biodiesel. The first major push for US ethanol was included in the National Energy Conservation Policy Act of 1978 (U.S. Congress 1978). It provided a subsidy of 40 cents per gallon of ethanol. The ethanol subsidy ranged between 40 and 60 cents per gallon between 1979 and 2011, when it ended. A subsidy for biodiesel also was added, which still exists in 2013.

The next major change was the creation of the Renewable Fuel Standard (RFS) in 2005 and its expansion in 2007 (U.S. Congress 2005; U.S. Congress, 2007). The RFS mandates a total of 35 billion gallons ethanol equivalent of different types of biofuels plus 1 billion gallons of biodiesel. Of that up to 15 billion gallons can be met with corn ethanol. Today about 40 percent of US corn (27 percent after accounting for the byproduct credit) goes into corn ethanol.

The biggest issue faced by the ethanol industry today is what is called the blend wall (Tyner and Viteri, 2010; Tyner et al., 2010). This effectively limits the ethanol blend in US gasoline to 10 percent. Since total US gasoline type fuel consumption is 133 billion gallons, the blend limit is about 13.3 billion gallons. However, the 2013 RFS level is 13.8 billion gallons—more than the amount that can be physically blended. This poses a significant challenge to the industry.

From the early days of biofuels, their environmental benefits have been touted as an important advantage over fossil fuels (Tyner, 2008). Biofuels were believed to reduce direct emissions from automobile fuel consumption and to reduce life cycle greenhouse gas (GHG) emissions due to the renewable nature of the feedstocks used (Farrell et al., 2006). Direct emissions are calculated based upon the emissions associated with the growth of the biomass feedstock, transportation to a processing facility, emissions from the conversion to a biofuel, and emissions connected with the transport and distribution of the biofuel to the ultimate automobile consumer. In this context, direct emissions are sometimes characterized as ‘field to wheel’, analogous to the ‘well to wheel’ measures for fossil fuels. In the U.S., most estimates of direct emissions are done using the GREET model developed at Argonne National Laboratory (Wang, 1999). GREET comprises all emissions associated with feedstock production including fertilizer, planting, chemical applications, harvest, etc., and estimates the efficiency of conversion of the biomass material to biofuels. Most of the direct emission estimates conclude burning a mega joule worth of corn based ethanol produces less GHG emissions than getting the same amount of energy from fossil fuels.

As more research has been done on environmental impacts of biofuels, it has become clear that some of the early promise of

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reduced emissions has not been fulfilled. One of the largest sources of potential GHG emissions associated with biofuels results from the indirect land use change (iLUC) induced by the biofuels-augmented demand for feedstock. We call this a *market-mediated response* and it will be the focal point of this survey. iLUC can be illustrated with the case of corn ethanol produced in the US, which has now surpassed corn fed to animals—previously the pre-dominant use of US corn. When government support encourages more use of corn for ethanol, ethanol producers must outbid current buyers using it for feed and food. All else equal, this will lead to an increase in the price of corn. Due to the higher price, there will be more corn grown to satisfy the enlarged demand. This additional corn production can come from intensification on existing corn land, crop switching to allow for more corn area, and/or from conversion of pasture or forest to cropland. It is this latter possibility that we call induced land use change. It causes GHG emissions because when land cover is converted, stored carbon in the wood or pasture is released by fire or decay and also an opportunity to store additional carbon in the future is sometimes foregone. The increase in emissions due to this iLUC is added to the direct emissions to get total GHG emissions for the biofuel.

The possibility of iLUC-related emissions was first raised in the seminal work of Searchinger, et al., who estimated that corn ethanol actually increases GHG emissions, relative to gasoline (Searchinger et al., 2008). Since this original study, many other analyses have been published, generally finding much lower indirect GHG emissions, thereby suggesting a more nuanced picture (Tyner and Taheripour, 2012; Wang et al., 2011; Hertel et al., 2010). In addition, other environmental impacts of biofuels have now been considered in greater detail (National Research Council, 2011). Most of these early studies relied heavily on simulation models because there was too little production of biofuels to see actual land use change globally. The absence of empirical evidence behind these assertions of market-mediated effects stemming from the biofuels programs led to justifiable skepticism on the part of some industry supporters (Kim and Dale, 2011). However, the Kim and Dale data analysis ended in 2007, before the major biofuels boom, and this work has been criticized on other grounds as well (O'Hare et al., 2011).

In recent years, biofuel production has increased substantially, especially in the US and Brazil. And, when coupled with other factors, including growth in developing countries and the associated dietary upgrading, we can now see the expected results: (i) significant world price increases (Abbott et al., 2008; Abbott et al., 2011) and (ii) global crop harvested area expansion as shown in Fig. 1. During the period of the 'biofuels boom', 2006—2011, we see that global harvested area for major field crops rose by 42 million hectares. Furthermore, as shown in Fig. 2, a large share of these increases have come in crops which are used in biofuels (corn, oilseeds), and the land cover change has been global in scope (Fig. 3)—suggesting that the transmission of these price signals through world markets is indeed an effective means of stimulating land use change.

Clearly, there have been many other drivers of changes in agricultural commodity prices and cropland expansion beyond biofuels (Abbott et al., 2008, 2011; Timmer 2008; Trostle et al. 2011). In 2011, Abbott, Hurt and Tyner indicate that the largest drivers of commodity price increases were biofuels and Chinese demand for soybean imports (Abbott, Hurt et al., 2011). However, regardless of the source of US corn price change, the impact on international land use is evident. Indeed, Villoria and Hertel (2011) estimate a statistical model which relates international changes in coarse grains area harvested to changes in US corn prices, while

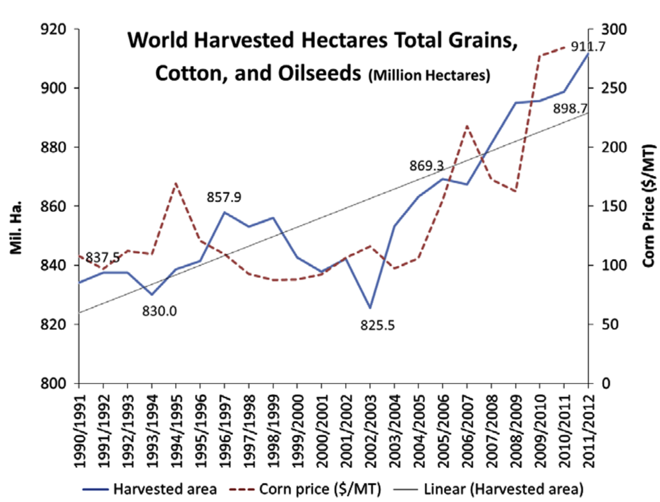

Fig. 1. Global harvested area for grains, cotton and oilseeds (solid line) and corn price (dotted line) for crop years from 1980/81—2010—2010/2011.
Source: USDA, WASDE, and USDA feed grains data base.

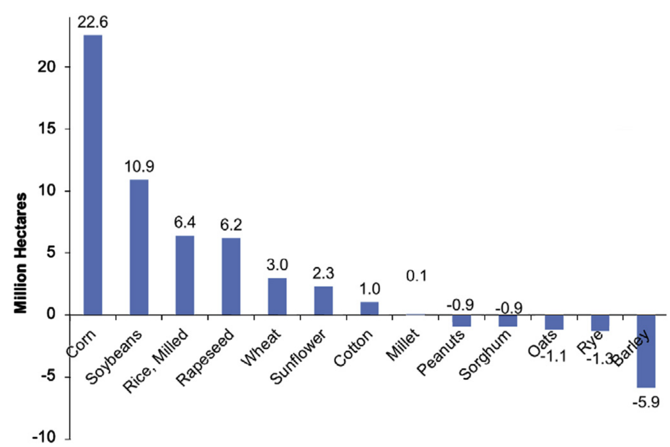

Fig. 2. Change in World Harvested Area, by crop, 2011/12—2005/06 (positive number corresponds to a rise in harvested area for a given crop).
Source: USDA WASDE

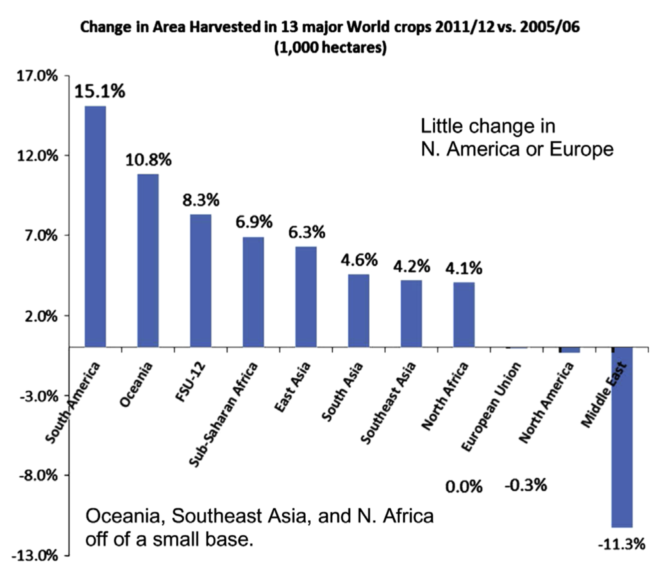

Fig. 3. Change in Harvested Area by Region (million hectares) for the 13 crops reported in Fig. 1. Results reported as the difference: 2011/12—2005—2005/6 crop years. A positive number indicates a rise in harvested area for that region.
Source: USDA WASDE