Regulation of GHG emissions from biofuel blended energy

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Outline

1. Direct emissions
2. Indirect emissions
3. A target number for regulators
4. Further research

Motivation

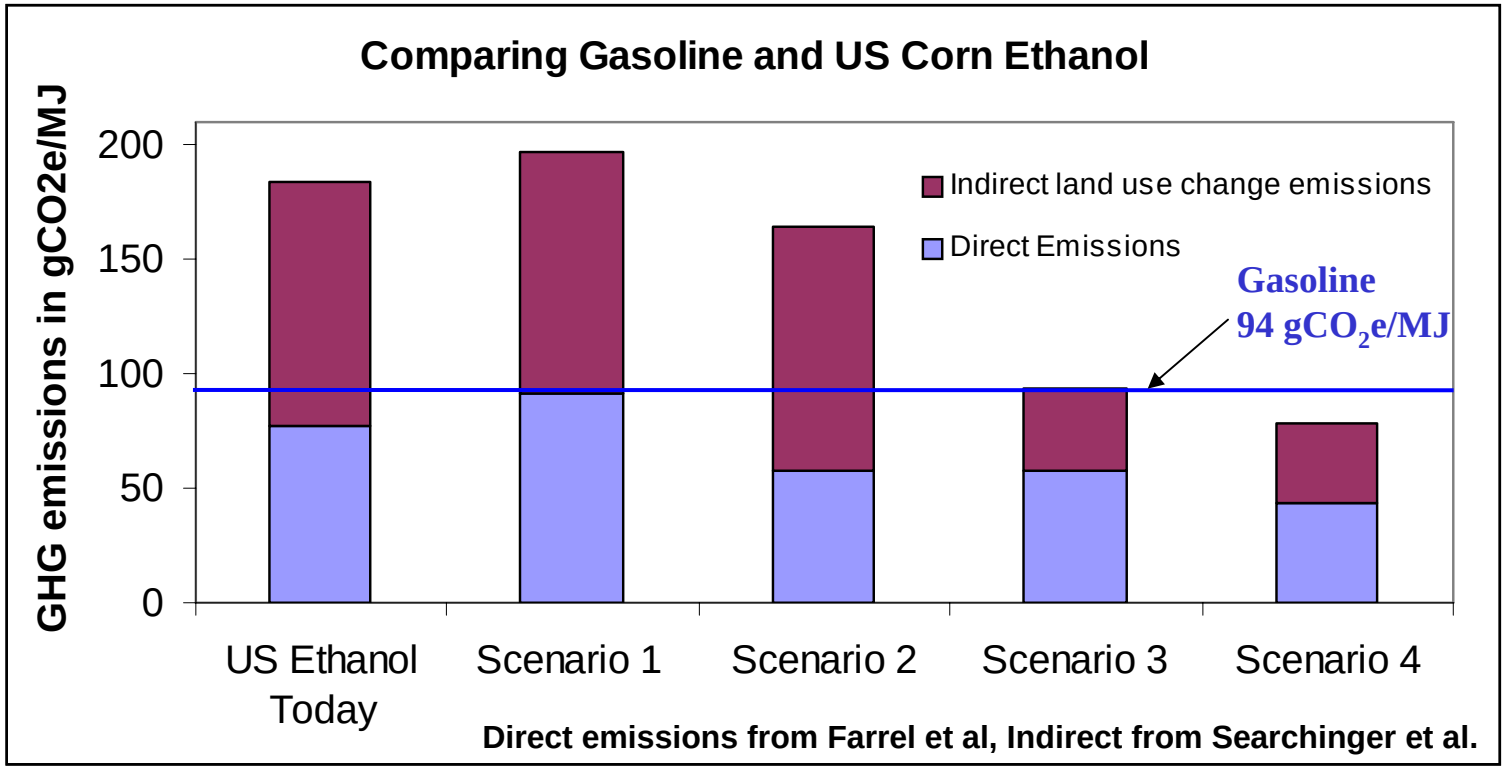
- *Policies such as LCFS (Calif.), RGGI (New England) and ETS (EU) aim to regulate carbon*

- *In a second-best (non-carbon tax) world which involves biofuels a lifecycle based approach to emissions is essential*

- *This is because while carbon emitted during combustion of biofuel is recaptured by biomass the upstream emissions are significant and need to be measured and allocated to biofuel blends*

Biofuels and GHG emission

Controlling both direct & indirect emissions is crucial



Scenario 1: Coal based biorefining (increases direct emissions)

Scenario 2: Natural gas based biorefining (lowers direct emissions)

Scenario 3: NG based biorefining and Indirect emissions equal to 1/3rd of Searchinger et al.'s estimate

Scenario 4: NG gas based biorefining, 39% improvement in corn yield, 25% reduction in energy for processing and indirect emissions equaling 1/3rd of Searchinger et al.'s estimate

Direct Emissions

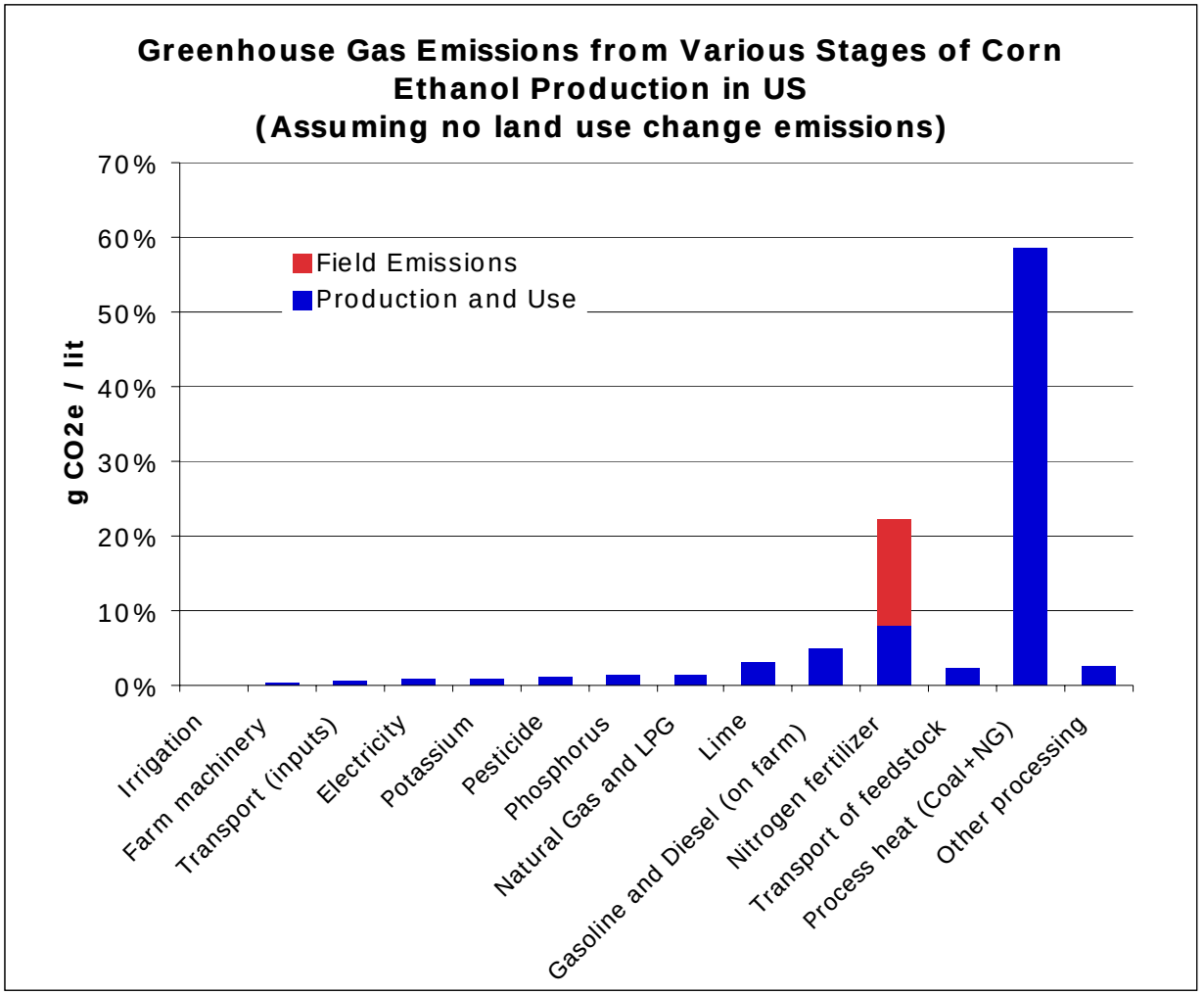
All emissions directly attributable to given batch of biofuel

We further categorize them into

1. **Direct onsite emissions**
   - Emissions at the regulated site say refinery or power plant
     - Emissions due to conversion of corn to ethanol

2. **Direct offsite emissions**
   - Emissions upstream or downstream related to production of intermediate inputs
     - Emissions from production and/or application of fertilizer

Direct emissions - Lifecycle of corn ethanol in US



Based on EBAMM data of Farrell et al. (*Science 2006*)

Measuring Direct Emissions

Requires a LCA type accounting of emissions

- Current process LCA which was developed for industrial emissions from a point source is a good starting point
- But it is not well developed for agricultural emissions or heterogeneous, distributed sources
- Our sensitivity analyses shows there are a few key stages in the lifecycle that are the most critical
  - Production and use of fertilizer
  - Conversion of biomass to fuel/energy

Indirect Emissions

Emissions accompanying induced expansion or intensification of agriculture

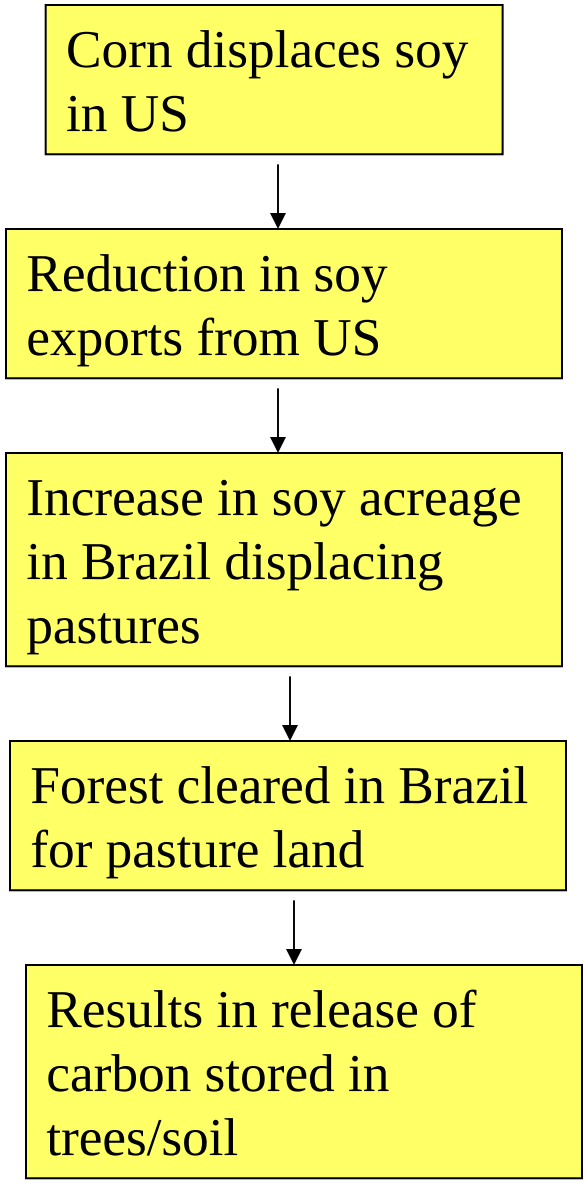
- Example of extensification is induced conversion of non-cropland such as pastures or forestland to agriculture

- Example of intensification is greater use of energy-intensive inputs like fertilizers in response to increase in output prices

- Unlike direct emissions they cannot be traced to a single biofuel producer and they may occur at locations far away from a biofuel production site

Indirect Emissions

- *These effects arise from interaction of markets for several commodities and across the globe*
- *Land may not be converted directly to be planted with bioenergy crop but planted to a crop displaced by biofuel crop*

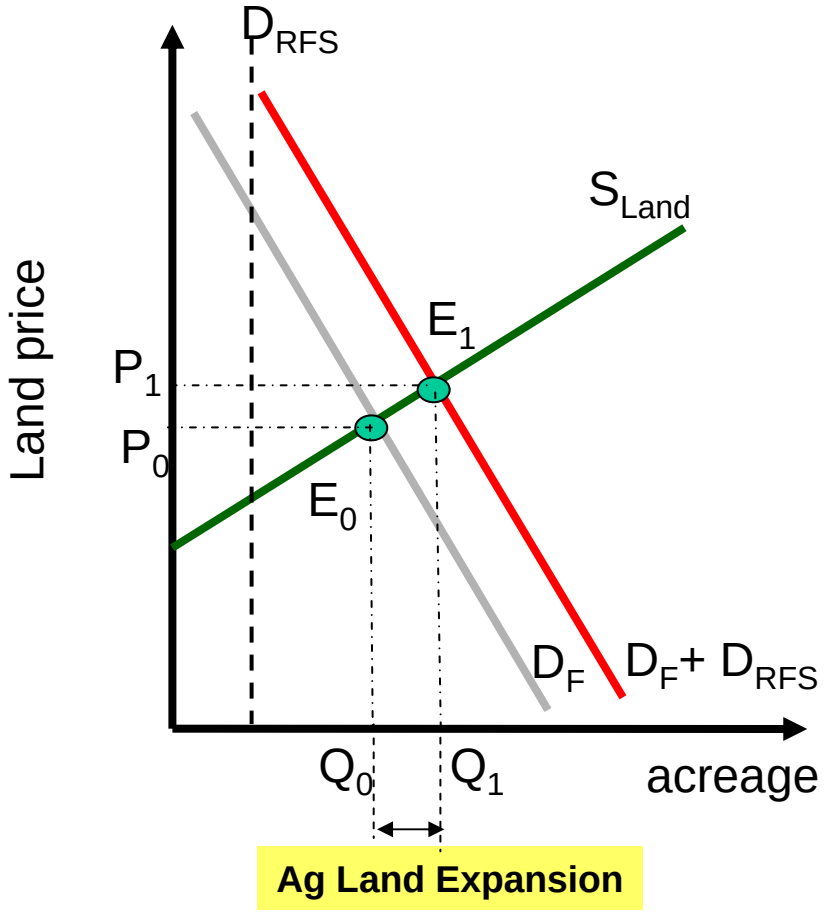


Indirect land use change – *Measurement*

Requires an economic equilibrium approach

- Has to be estimated in aggregate using aggregate supply and demand equilibrium for land

- After controlling for factors like economic growth, weather shocks, inflation, exchange rate etc.



Searchinger et al.’s estimate

Mandate of 56 billion liters of ethanol in US (assumed to be corn based)

⇓

140 million tonnes of corn @ 2.7 gallons of ethanol per bushel of corn

⇓

Global agricultural acreage to expand by 10.8 million hectares

Alternative calculation - Back of envelope

Land use change can be hypothesized using historical data on elasticity of acreage with respect to output

- Between 1950 and 1998, global agricultural output increased 150% while harvested acreage increased only 13% implying elasticity, $\varepsilon_{L/Q} = \frac{\Delta L/L}{\Delta Q/Q} = \frac{0.13}{1.5} = 9\%$

i.e, historically when output increased by 100% land under agriculture increased by 9%

Using this value expansion is 3.3 million hectares

Comparing the two numbers

- **Our back of envelope estimate may be too optimistic**
  - If we break down historical trend into smaller time periods, elasticity of acreage is variable with values lower than zero and higher than 0.5
  - Future expansion may occur on marginal land with low yield

- **But at the same time Searchinger et al's may be an overestimate**
  - Recent trends in yield may not be a good indicator because of declining investments in R&D and declining output prices

A better approach is to use an equilibrium model but accounting for history and the role of prices and policies to induce technical change

Indirect Emissions – *Allocations*

After determining the aggregate indirect effect it can be allocated across all producers

- Each individual farmer is too small to cause a significant indirect expansion but in aggregate they do
- Analogous to the idea of a price-taking producer in a competitive market – each farmer takes an average number for indirect emissions per unit of land or per unit of biofuel as given
- This can be scaled by a crop or technology specific factor to account for differences production characteristics

A target number for regulation

Comparing the sum of direct and indirect emissions to a standard

Let $\bar{f}$ be the carbon standard set by the regulator per unit of fuel

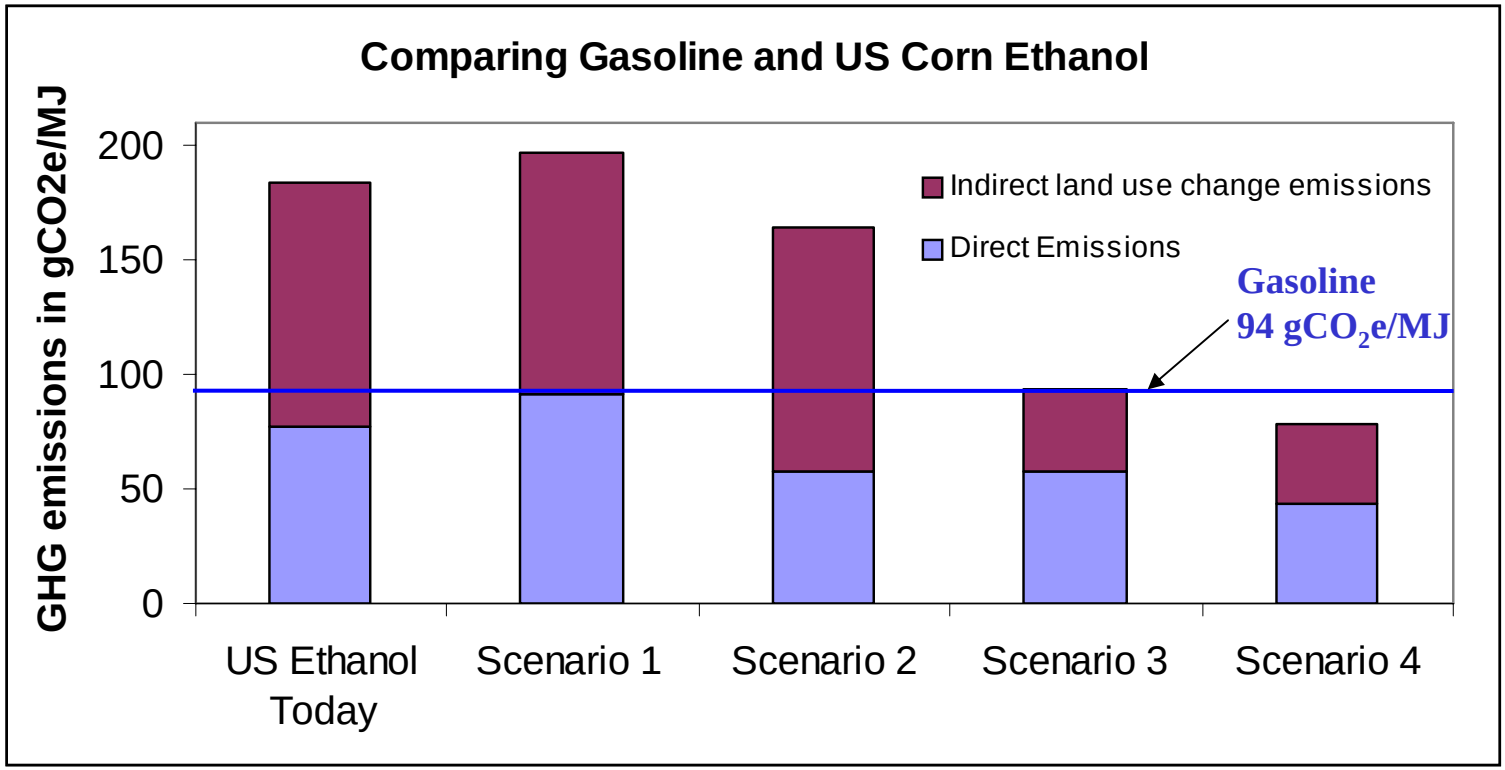
For example $\bar{f}$ may be the emissions from the marginal fossil fuel

Then the regulated site must ensure that, $f_D < \bar{f} - f_I$

where, f_D and f_I are the direct and average indirect emissions per unit of fuel, and $f_I = \frac{F_I}{V}$

where F_I is the total indirect emissions and V is the volume of biofuel in the market from a given region due to a given policy

Illustration of the framework



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Summary

- Biofuel emissions are heterogeneous – vary with feedstock, technology and location

- Both direct and indirect emissions are crucial

- We have outlined a simple framework for regulation – one that compares the sum of direct and indirect emissions to a standard

- Promising approach but needs further investigation into several aspect (see next slide)

Other issues and further research

- Traceability, certification, monitoring, and the transaction costs of such an approach

- Developing a clear and robust methodology for calculating direct emissions

- Developing a clear and robust methodology for estimating indirect land use

Acknowledgement

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