Petroleum Refining and the Indirect Byproduct Effect of Biofuels

Geoffrey Barrow, Gal Hochman, and David Zilberman

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Introduction

Recent debates on the environmental benefits of biofuels have focused on the negative GHG effects of indirect land use change.

We identify an unrecognized indirect effect of biofuels resulting from decreased supply of petroleum byproducts—i.e., the indirect byproduct effect (IPPDE).

This effect represents the change in GHG associated with the displacement of petroleum byproducts which are eliminated or replaced with reduction in transportation fuel.

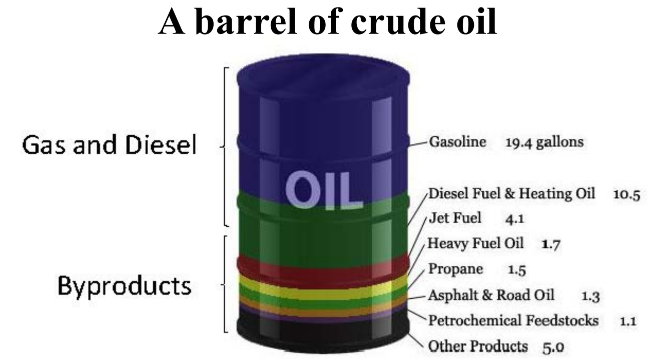
A range of values to capture the order of magnitude of this effect are derived, and we find that it is likely to reduce the GHG emissions associated with biofuels and thus serve to offset the negative effect of indirect land use changes.

Stylized numerical analyses suggest that when the IPPDE is included in the LCA, corn-based ethanol easily meets minimum requirements for renewable fuel credits under the Renewable Fuel Standards.

The IPPDE effect

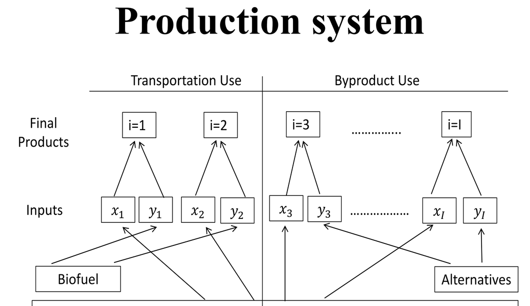
The petroleum refining process is an industrial process whereby crude oil is processed and refined, and petroleum products produced.

A barrel of crude oil



The IPPDE is defined as the change in GHG emissions associated with changes in petroleum byproduct supply resulting from increased biofuel use.

Production system



The numerical analysis

Other parameters used:

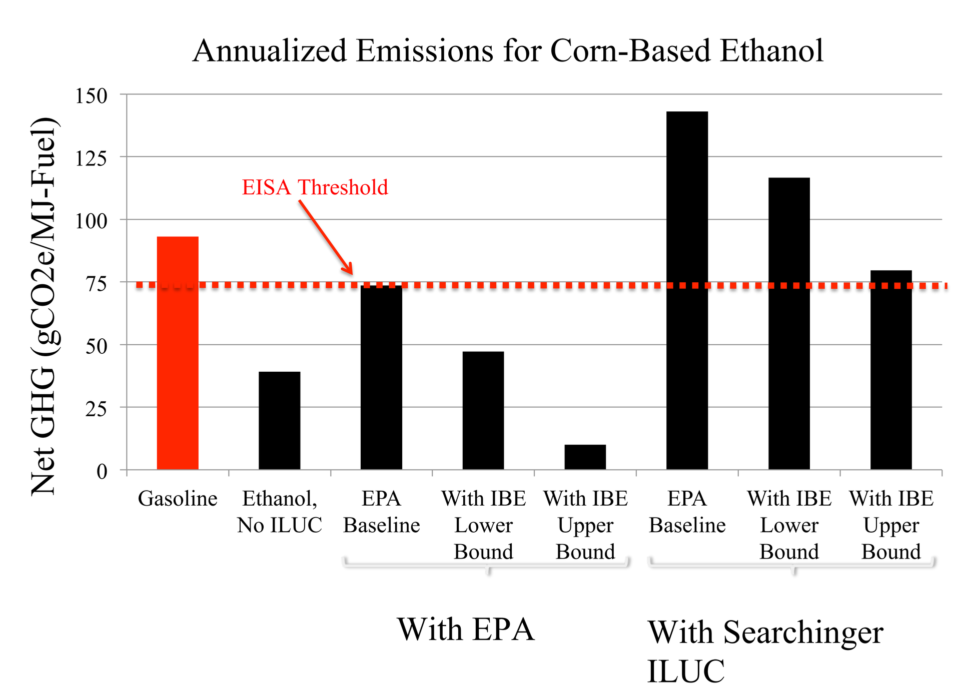
Time Horizon (Years)	30.00
Discount Rate (%)	0.00
α	0.12
ϵ	0.08
γ^0	0.36
Motor Fuel Demand 2022 (Billions of Barrels of Oil Equivalent)	196
Ethanol $mmBTU/Barrel$	3.2
Natural Gas gCO_2e/MJ	74.44
Coal gCO_2e/MJ	99.89
Concrete gCO_2e/MJ	37.53

The Byproduct parameters:

Byproduct	$x(Barrels)$	$l(GJ/Barrel)$	$e(gCO_2e/MJ)$	$y(Alternative)$
Asphalt	131035000	7.07	69.77	Concrete
Coke	292000000	6.74	99.46	Coal
Heating Oil	525599000	6.15	94.80	Natural Gas
Jet Fuel	510270000	5.33	91.83	None
LPG	229950000	4.14	84.46	Natural Gas
Other Products	227030000	6.34	81.00	None
Residual Fuel	218635000	6.64	214.92	Natural Gas
Still Gas	235790000	6.64	65.10	Natural Gas

Notes: $x(Barrels)$ is the production of byproduct in the US in 2009 expressed in barrels per year. Data comes from EIA. $l(GJ/Barrel)$ is the energy intensity of the byproduct. Data comes from Canada National Energy Board. $e(gCO_2e/MJ)$ is the emissions intensity associated with consumption of the byproduct. $y(Alternative)$ is the assumed alternative for replacement scenarios.

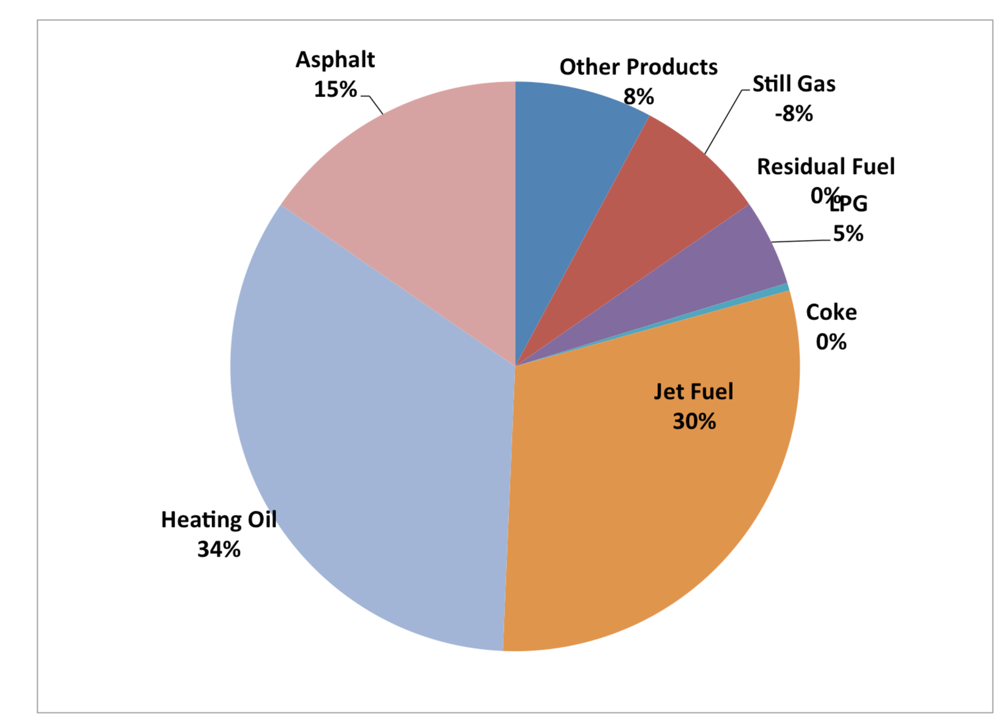
Results



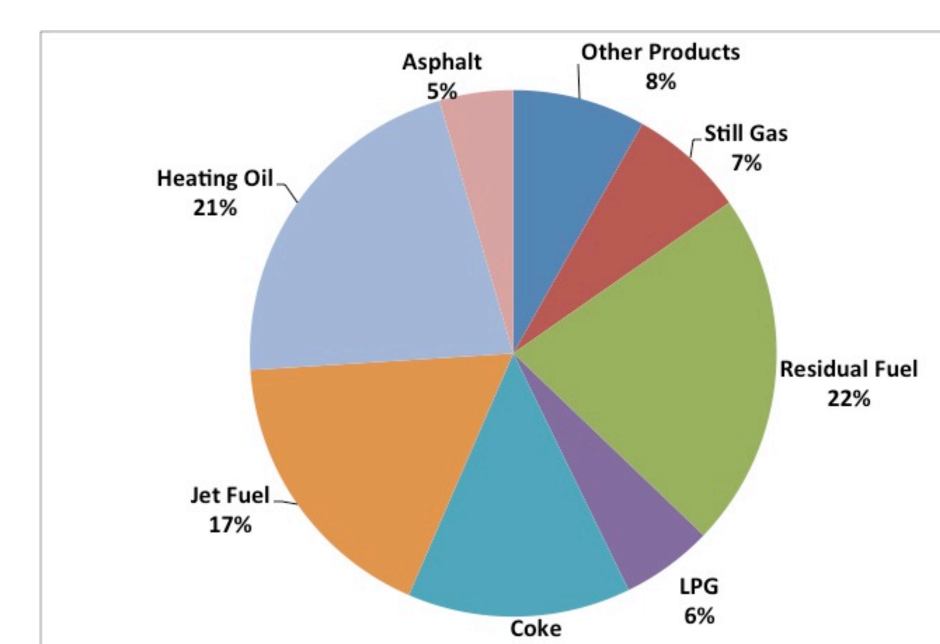
- Without including ILUC, the EPA calculates the annual emission of corn-based ethanol to be 39 gCO2e/MJ, compared to 92 gCO2e/MJ annual emissions for gasoline (first two columns of Figure 1).
- When the EPA includes ILUC, it calculates corn-based ethanol emits 74 gCO2e/MJ per year, which represents 21% less GHG emissions than traditional gasoline (column 3 of Figure 1).
- By contrast, including IPPDE in the EPA's LCA (with ILUC), we find in columns 4 that corn-based ethanol emits between 28 and 50 gCO2e/MJ, which represents between 46% and 70% less GHG emissions than traditional gasoline, depending on the assumption about adjustment.

Using the Searchinger et al. estimates, without including IPPDE, corn-based ethanol emits 143 gCO2e/MJ, or 54% more GHGs than gasoline (column 5). Including the IPPDE estimate under fixed proportion assumption, corn-based ethanol emits 97 gCO2e/MJ (column 6).

We assume fixed proportion technology in this figure, and fixed proportion of individual byproduct shares throughout.



Byproduct contributions to GHG savings under *full* replacement.



Byproduct contributions to GHG savings under *no* replacement.

The reason for the more even distribution under the assumption of no replacement, is that the emissions differentials are all on the same order of magnitude, unlike in the full replacement case, in which we assume the emissions differential from jet fuel and heating oil to be much larger than the differentials associated with the remaining byproducts.

Conclusions

- The analysis demonstrates that changes in GHG emissions resulting from an increase in biofuels depend, not only on motor fuel products (gasoline and diesel), but on the petroleum byproducts as well.
- Although the environmental impacts of decreased petroleum byproducts is uncertain, the GHG reductions from the IPPDE could be large and have direct policy implications.
- The analysis suggests that if indirect effects are considered in biofuel policies, ignoring the IPPDE may lead to underestimation of the contribution of biofuels to GHG emissions reductions.
- The feedstock for advance biofuels offer significantly higher yields and do not compete with the food supply, which means the indirect effects on land-use change will be much smaller. However, the IPPDE on GHG reductions is the same regardless of the biofuel technology replacing gasoline and diesel, which suggests that advance biofuels may carry even larger environmental benefits than are currently believed.

Acknowledgments

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For further information

Geoffrey Barrow is a PhD student at University of California Berkeley (geoffrey.barrows@gmail.com).

Gal Hochman is an Associate Professor at Rutgers University (gal.hochman@rutgers.edu)

David Zilberman is a Professor at University of California Berkeley (zilber11@berkeley.edu)