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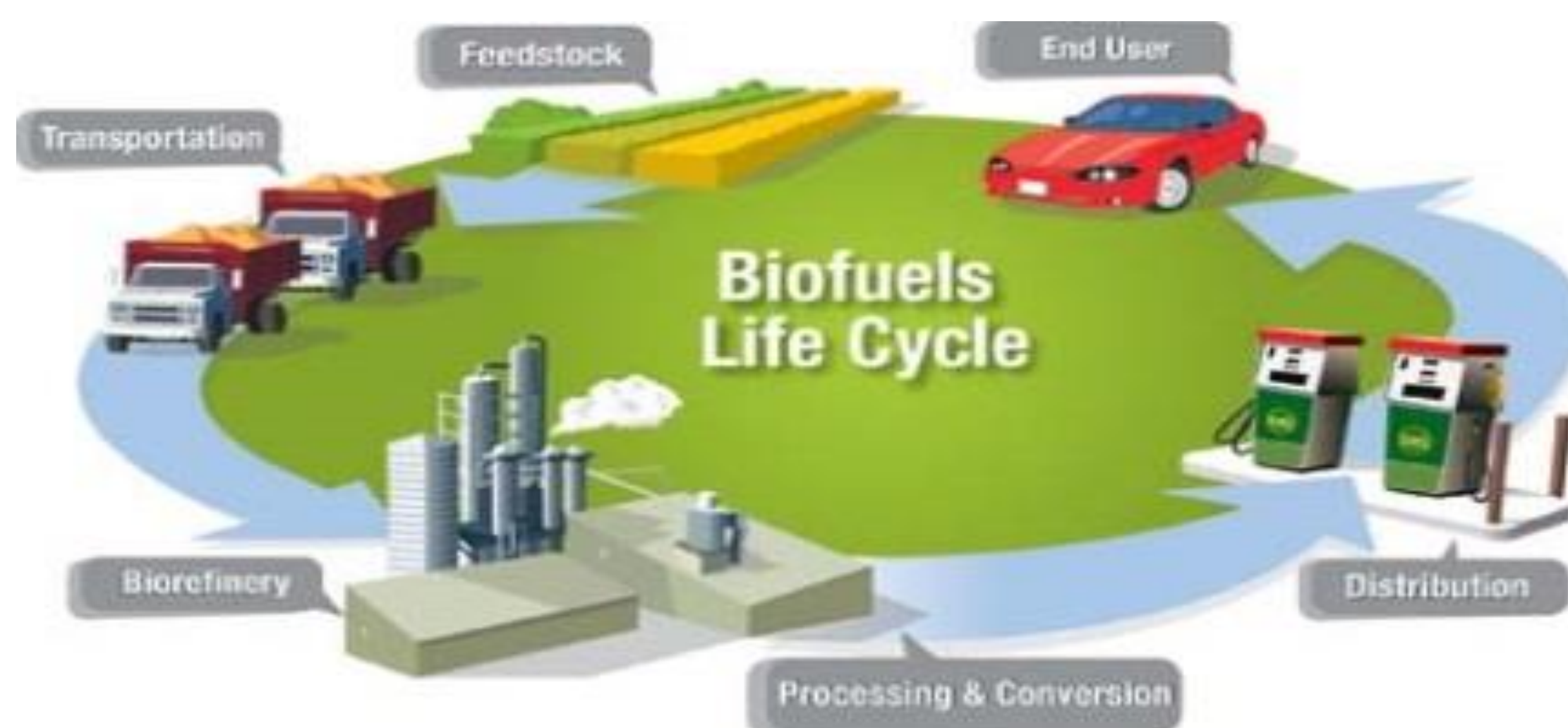
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Substitution Elasticities between GHG Polluting and Non-polluting Inputs in Agricultural Production: A Meta-Regression

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Motivation

There is ongoing debate on whether biofuel can reduce GHG emissions. Measurement of GHG emissions from biofuel is typically examined through life-cycle analysis (LCA), which assesses the emissions associated with the entire life of a biofuel, from production of feedstock to end use. Previous studies on LCA generally assume fixed-proportions production functions. However, a change in the relative price of an input that generates GHG emissions could induce substitution away from that input and alter emissions and environmental policy consequences. As a result, it is important to allow for substitutability between GHG-polluting inputs and non-polluting inputs at every stage of biofuel production, including the production of feedstock, of which agricultural crops are currently the primary source in the U.S.



The biofuel life cycle—from feedstock to end user. (Source: DOE)

Objectives

To investigate substitution elasticities between GHG polluting input and non-polluting inputs in agriculture production relevant to U.S. biofuel feedstock by using a meta-regression.

Input Categories

GHG polluting input

- Energy, fertilizer, and manure are treated *collectively* as the GHG polluting input

Non-polluting inputs

- Labor, land, and capital

Meta-Regression

Why meta-regression?

- Prior estimated elasticities of input substitution in agricultural production vary considerably
- Identify the sources of variation in prior empirical estimates and provide conditional summary statistics of estimates and help

What is meta-regression?

- Observations used for the dependent variable are estimates from prior empirical studies
- Independent variables are factors relevant for explaining the heterogeneity of prior estimates

Choice of Dependent Variable

- Morishima elasticities of substitution (MES) for each non-polluting input vs. polluting input
 - Measuring changes in the ratio of a non-polluting input and the polluting input as the price of the polluting input varies

Meta-regression Sample

- 65 empirical studies including 264 MES estimates for labor (MES_{lp}), 136 for land (MES_{dp}), and 303 for capital (MES_{kp}) vs. the polluting input

Choice of Independent Variables

- Dummy variables
 - Emphasizing uncton type, functional form, technology, model structure, data characteristics, estimation methods, and measurement of output
 - Indicating elasticities of substitution in biofuel feedstock production in the U.S.
- A Continuous variable correcting for publication bias
 - Using inverse of square roots of sample sizes in prior empirical studies
- Eliminating 2 variables that are insignificant and cause severe multicollinearity

Econometric Method

- MES for labor, land vs. the polluting input
 - Reject random panel effects → Weighted least squares linear regression model
- MES for capital vs. the polluting input
 - Fail to reject random panel effects → Random effects panel data linear model

Robustness Check

- Using samples exclusive of negative MES observations that violate cost-minimizing curvature conditions

Reference Case Results

The reference case (i.e., when all dummies are equal to zero) is regarded as the most pertinent for agricultural feedstock production in LCA models.

- It represents a *long-run MES between the polluting input of energy, fertilizer, and manure and non-polluting inputs for a study that includes aggregate labor, land, and capital as non-polluting input categories. It is based on a static translog cost function with non-neutral technological change and non-constant returns to scale that treats U.S. aggregate agriculture as a single output, includes post-1981 time series data, and uses a maximum likelihood estimator.*

➤ Estimated MES in the reference case

MES_{lp}	$MES_{lp}>0$	MES_{dp}	$MES_{dp}>0$	MES_{kp}	$MES_{kp}>0$
2.861***	2.977***	1.420**	1.772***	1.075**	1.414*
(0.626)	(0.626)	(0.557)	(0.524)	(0.649)	(0.678)

Note: Estimates for the samples restricted to positive MES values are reported in the 2nd, 4th, and 6th columns; ***, **, * =statistically significant at 1 percent, 5 percent and 10 percent level, respectively; standard errors are in parentheses.

Conclusions

- Heterogeneity of MES can be mostly explained by function type, functional form, data characteristics, input and output measurement, time and country categories.
- Each estimated long-run MES for the reference case, which is most relevant for assessing GHG emissions through LCA, is greater than 1.0 and significantly different from zero.
- Most MES estimates remain significantly different from zero at the data means when cost-minimizing curvature is satisfied.
- **These findings imply that the life-cycle analysis based on fixed proportions production functions could provide grossly inaccurate measures of GHG of biofuel.**



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