Farm Foundation and ERS Workshop
Global Biofuel Developments: Modeling the Effects on Agriculture

CARD Ethanol Model: An Approach to Modeling Ethanol Markets and Scenario Analyses

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Outline

- Description of the CARD Ethanol Model
  - U.S. ethanol model
  - Brazilian ethanol model
  - China, EU-25, India models
  - Japan, South Korea and the Rest of the World

- Summary Results of Some Scenario Analyses
  - Removal of trade and domestic distortions in the U.S.
  - Price shocks (crude oil price, corn price, sugar price)
  - Long-run equilibrium analysis
Outline of CARD Ethanol Model

- Non-spatial multi-market model
- Behavioral equations for production, consumption, ending stocks and net trade
- Solves for a representative world ethanol price
- Domestic ethanol prices linked to world price through price transmission equations
- Incorporates linkages between agricultural commodity markets and energy markets
U.S. Ethanol

- Energy Policy Act of 2005
- Federal Tax Credit
- Trade Policy
  - Import tariff and duty
  - CBI agreement
- Ethanol, Corn and Crude Oil Link
- Expanding Production Capacity
U.S. Ethanol Model

- Fuel Ethanol demand
  
  - A derived demand from the cost function for refiners blending gasoline with additives including ethanol
  
  \[ C = C(P_{Ethanol}, P_{CrudeOil}, Policy, Q_{GasolineSupply}) \]

  \[ C = \tilde{C}(P_{Ethanol}, P_{CrudeOil}, Policy) * Q_{GasolineSupply} \]

  - Demand for fuel ethanol = \( \frac{\partial C}{\partial P_{Ethanol}} \)

  \[ E_{Fuel} = \frac{\partial C}{\partial P_{Ethanol}} = Q_{GasolineSupply} * \left( \frac{\partial \tilde{C}}{\partial P_{Ethanol}} \right) \]
U.S. Ethanol Model

- Fuel Ethanol Demand
  \[ \frac{\partial C}{\partial P_{\text{Ethanol}}} = f(P_{\text{Ethanol}} - \text{Taxrebate}, P_{\text{CrudeOil}}, \text{Mandate}, \text{RFS}) \]

- \[ Q_{\text{GasolineConsumption}} = g(P_{\text{Gasoline}}, P_{\text{Ethanol}}, \text{Taxrebate}, \text{GDP}, \text{Population}) \]

- In equilibrium \[ Q_{\text{GasolineSupply}} = Q_{\text{GasolineConsumption}} \]

- \[ E_{F^*} = \frac{\partial C}{\partial P_{\text{Ethanol}}} = f(P_{\text{Ethanol}} - \text{Taxrebate}, P_{\text{Gasoline}}, \text{Mandate}, \text{RFS}) \]
  \[ \times g(P_{\text{Gasoline}}, P_{\text{Ethanol}} - \text{Taxrebate}, \text{GDP}, \text{Population}) \]
U.S. Ethanol Model

- Fuel Ethanol Demand
  - At the equilibrium of the gasoline market, $\frac{\partial \tilde{C}}{\partial P_{\text{Ethanol}}}$ can be interpreted as the share of fuel ethanol in total gasoline consumption $\frac{E_{F^*}}{Q_{\text{GasolineConsumption}}}$

- Total Ethanol Demand = Fuel Ethanol Demand + Residual Ethanol Demand
U.S. Ethanol Model

- **Fuel Ethanol Production**

  - *Production* = \( h \) (Net Revenue, (Production Capacity))

  - \( \text{Net Revenue} = \pi^{NET} = \gamma_E \cdot P_{\text{Ethanol}} + (s_{WM} \cdot ((\gamma_{GF} \cdot P_{GF}) + (\gamma_{GM} \cdot P_{GM}) + (\gamma_{CO} \cdot P_{CO}))) + (s_{DM} \cdot (\gamma_{DDG} \cdot P_{DDG})) - P_{\text{Corn}} - m \cdot P_{\text{NaturalGas}} \)

  - \((\text{Production Capacity})_t = (\text{Production Capacity})_{t-1} \ast (1 + \text{Growth Rate of Capacity})\)

  - \( \text{Growth Rate of Capacity} = g_t = \begin{cases} k(\pi^{NET}_{t-1}, E(D_E)) & \text{if } \pi^{NET}_{t-1} > 35\$ \text{ per bushel} \\ 0 & \text{Otherwise} \end{cases} \)
U.S. Ethanol Model

- Trade Equations
- Trade Policy Parameters:
  - *In quota tariff rate* $t^i = 0$
  - *Out-of-quota tariff rate* $t^o = 2.5\% \text{ plus } 54 \text{ cents per gallon}$
  - *Tariff rate quota (CBI)* $= 60 \text{ million gallons or } 7\% \text{ of consumption, whichever is greater}$
  - *Transportation cost* $t_c = 11 \text{ cents per gallon}$

- *US Imports* $= \text{Imports from CBI} + \text{Imports from Other}$
U.S. Ethanol Model

- Trade Equations for CBI

\[
M_{CBI} = \begin{cases} 
\alpha + \beta \cdot \left( \frac{P_{US}^{US}}{P_E^W \cdot (1 + \tau^A)} + tc \right) & \text{if } P_E^{US} > \theta \cdot (P_E^W \cdot (1 + \tau^A) + tc) \\
M_{CBI} = 0 & \text{if } P_E^{US} > \phi \cdot (P_E^W \cdot (1 + \tau^A) + tc) \\
M_{CBI} = 0 & \text{Otherwise}
\end{cases}
\]

- \( t^A = t \) if \( M_{CBI} \leq TRQ \)

- \( t^A = \tau \) if \( M_{CBI} > TRQ \)
U.S. Ethanol Model

- Trade Equations for Other Imports

\[ M_{Other} = \begin{cases} 
0 & \text{if } P_{US} < \phi \cdot (P_{E}^{W} \cdot (1 + \tau) + tc) \\
(Demand - Supply) & \text{Otherwise}
\end{cases} \]

- Price-switching mechanism
  - When tariff is prohibitive, the domestic price is solved endogenously
  - When the tariff is not prohibitive, the domestic price is determined through a price transmission equation
Brazilian Ethanol

- Mandate on Ethanol Mix with Gasoline
- Lower Excise Tax on Ethanol Use
- Ad valorem Duty
- Tax Incentives on Ethanol and Flex-fuel Vehicles
- Sugar and Ethanol Link
Share of Brazilian Vehicle Fleet

2004

2015

Flex-fuel Alcohol Gasohol

Flex-fuel Alcohol Gasohol
Brazil Ethanol Model

- Fuel Ethanol Demand
  - Anhydrous and hydrous demand
    
    \[
    C^{Anhydrous} = f(P_{Ethanol}, P_{Gasoline}, InteractionTerm, GDP, Population, Blend)
    \]
    
    \[
    C^{Hydrous} = g(P_{Ethanol}, P_{Gasoline}, InteractionTerm, GDP, Population, FlexfuelCars)
    \]
    
    \[
    InteractionTerm = FlexfuelCarsRatio \times P_{Gasoline}
    \]
Brazil Ethanol Model

- Ethanol Production
  - From cane producers profit maximization in the Brazilian sugar model
    
    \[ AHA_t = h(AHA_{t-1}^{\text{Cane}}, P_{\text{Sugar}}, P_{\text{Ethanol}}, P_{\text{AlternativeCrop}}) \]

  - SugarcaneProduction = \( AHA_t^{\text{Cane}} \times \text{Yield}_t \)

  - Share of Sugarcane in Ethanol Production = \( j \) (Relative price of Ethanol to Sugar)
Brazil Ethanol Model

- Ethanol Production
  - Sugarcane in ethanol production = Share of sugarcane in ethanol production * Total sugarcane production
  - Ethanol production = Sugarcane used in ethanol production * Conversion rate

- Stocks
  - Ethanol Ending Stocks = \( k(P_{\text{Ethanol}} \text{ Beginning stocks}) \)

- Net Trade
  - Net Exports = Production + Beginning Stocks – Consumption – Ending Stocks
Other Country Models

- EU-25, China, India
  - Ethanol Consumption or Disappearance
  - Ethanol Production
  - Change in Stocks (EU-25)

- Japan, South Korea and Rest of World
  - Net Trade Equations

- ROW closes the model.
Scenario Analyses

- Removal of U.S. Import Tariff
- Removal of U.S. Volumetric Ethanol Excise Tax Credit (VEETC)
  - *Removal of U.S. Ethanol Domestic and Trade Distortions: Impact on U.S. and Brazilian Ethanol Markets*
- Price Shocks (World crude oil, U.S. corn, world sugar)
  - *An Analysis of the Link between Ethanol, Energy, and Crop Markets*
- Long-run Equilibrium Analysis
  - *The Long-Run Impact of Corn-Based Ethanol on the Grain, Oilseed, and Livestock Sectors: A Preliminary Assessment*

http://www.card.iastate.edu/publications
Extensions to the Model

- Fuel Ethanol demand
  - Fuel ethanol demand in the U.S. model to be split into three components
    - Additive Market
    - E-10 Market
    - E-85 Market

- Links to the U.S. and International Livestock and Dairy Sectors

- Biodiesel
THANK YOU