The World Fertilizer Model

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Round table: Projections and economic modelling in agriculture
Buenos Aires, Argentina

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Overview

• Intro

• Model description
  – Macro-nutrients
  – Country coverage
  – Commodity coverage
  – Linkage to global commodity model
  – Data sources

• Ag outlook and scenario analysis
The World Fertilizer Model

World Fertilizer Model—The WorldNPK Model

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The World Fertilizer Model

• Project funding:
  – The David and Lucile Packard Foundation
  – The Biobased Industry Center (BIC) at Iowa State University.
The World Fertilizer Model

• Fertilizer model at a global scale
• Objective:
  – Fertilizer demand projections (by year)
  – by nutrient | by country | by commodity
• An optimal fertilizer application rate is solved for each crop in each country in each projection year
• Use projected crop areas, to project fertilizer demand, by crop, by country, by year
The World Fertilizer Model

• The model:
  – Can be implemented to fully interact with any global model of commodity markets
  – Improves precision of intensification component: yield response
  – GHG model, improves its N2O emissions output
  – Evaluate policies that affect fertilizer markets:
    • Policies on fertilizer products
      – Input taxes, subsidies
      – Restrictions on quantity use
      – Trade restrictions
    • Also other policies on commodity markets
Commodity Coverage

Can be implemented to fully interact with any global model of commodity markets

<table>
<thead>
<tr>
<th>Grains</th>
<th>Oilseeds</th>
<th>Other</th>
<th>Fertilizer</th>
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<tbody>
<tr>
<td>Wheat</td>
<td>Soybeans</td>
<td>Sugarcane</td>
<td>Nitrogen</td>
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<td>Rice</td>
<td>Rapeseed</td>
<td>Sugar beet</td>
<td>Phosphate</td>
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<td>Corn</td>
<td>Sunflower Seed</td>
<td>Cotton</td>
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<td>Barley</td>
<td>Peanuts</td>
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<td>Sorghum</td>
<td>Palm</td>
<td>Fruit &amp; Veg*</td>
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<tr>
<td>Oat/Rye</td>
<td></td>
<td>Oth crops*</td>
<td></td>
</tr>
</tbody>
</table>
Country Coverage, granis

For each country-commodity pair, project N, P and K application rates.
Country Coverage, oilseeds

For each country-commodity pair, project N, P and K application rates.
Country Coverage, sugar

For each country-commodity pair, project N, P and K application rates.
Country Coverage, by region

- **United States:**
  - Regions: CB, CP, DS, FW, LS, NE, SE, NP, SP
  - Crops: Wheat, Rice, Corn, Soybeans, Cotton, Sugar Beet, Sugarcane, Peanut, Rapeseed, Sunflower Seed, Barley, Sorghum, Oats

- **Brazil:**
  - Regions: N, NE, CW, SE, S
  - Crops: Wheat, Rice, Corn, Soybeans, Cotton, Sugarcane, Barley, Corn Safrinha

- **Argentina, no regions**
  - Wheat, Rice, Corn, Soybeans, Cotton, Sugarcane, Peanut, Sunflower, Barley, Sorghum
The application on FAPRI

International Prices

Price Transmission

Beginning Stocks

Yield

Area

Domestic Supply

Imports

Exports

Net Exports

Food Demand

Feed Demand

Other Demand

Ending Stocks

Domestic Demand

Trade Policy Content
The application on FAPRI

The World Fertilizer Model

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International Prices

Price Transmission

Imports

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Domestic Demand

World NPK model

Trade Policy Content
The application on FAPRI

- FAPRI crop yield equation: crop $y$, country $i$, time $t$

$$y_{it} = \alpha + \beta \text{Trend}_t + \delta \left( \frac{T \text{Rev}_{it}}{T\text{Cost}_{it}} \right) + \gamma \left( \frac{T \text{Rev}_{i10 \text{y-ave}}}{T\text{Cost}_{i10 \text{y-ave}}} \right) + \lambda a_{it} + \kappa \left( \sum a_{it} \right) + \varepsilon_t$$

- \(T\text{Cost}_{it} = F\text{Cost}_{it} + N\text{FCost}_{it}\)
- \(F\text{Cost}_{it} = p_{Nit} N_{it} + p_{Pit} P_{it} + p_{Kit} K_{it}\)

- Requires:
  Underlying yield response to nutrient N, P, K
The application on FAPRI

- Estimation of production elasticities
  - Response of crop yields to changes in nutrient application rates
  - Commodity-, Nutrient-specific (N, P and K)
Data sources, fertilizer rates

• Based on an in-depth data collection of historical fertilizer application rates by crop and country
  • “Assessment of Fertilizer Use by Crop at the Global Level”
    – 2006/07, 2007/08” (IFA 2009)
    – 2010/11” (IFA 2013)
  • “Fertilizers Europe data base on nutrient application rate by crop”. Fertilizers Europe 2010
  • International Fertilizer Industry Association, IFADATA 2013
  • “Fertilizer Use by Crop”. FAO 2006 (hereafter FAO 2006)
  • “Fertilizer Use by Crop”. FAO 2002 (hereafter FAO 2002)
  • “Fertilizer Use by Crop for Specific Countries” FAO 2002-2005 (hereafter FAO 2002-2005)
Data sources, fertilizer prices

- Model requires nutrient-specific prices per country: landed prices
- Data on fertilizer prices
  - Data collection on domestic prices
    - China, India, U.S., Brazil, EU-27 (73% of World’s use)
  - For the rest of the countries use a price transmission equation
    - International nutrient price (assume US prices of urea, Triple SP, K chloride)
    - Duties
    - Exchange rates
  - Fertilizer prices projected using “Cost of Production Model”
Institutions interested in results

- Bloomberg
- Princeton University - Woodrow Wilson School of Public and International Affairs
- The Monsanto Company - Sustainable Ag & Economics
- International Fertilizer Industry Association - IFA
- McKinsey
- Bunge
- Itau Bank (Brazil)

- Macquarie Securities, Canada
- Equity Research, Brazil
- Integer, UK
- Sanford Bernstein, UK
- Phoenix Capital, Ukraine
Use of the Fertilizer Model
Use of the Fertilizer Model

Research Article

Biofuel Expansion, Fertilizer Use, and GHG Emissions: Unintended Consequences of Mitigation Policies

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Aditional slides
Upgrades – Fertilizer Demand

• Production elasticities revisited
  – Yield response to N, P, & K application rates
  – $y_{ij} = f(N_{ij}, P_{ij}, K_{ij}, Cap_{ij}, L_{ij}, S_{ij}; \theta)$
  – Include data on country’s suitability to produce each crop
    • $S_{ij}$ : Global Agro-Ecological Zones (FAO & IIASA data), Suitability index (% achievable of potential yields)
      – Available by crop & by country
    • $Cap_{ij}, L_{ij}$: Ag Capital, Economic Active Pop/ha
      – FAO
The application on FAPRI

- Alternatives: fertilizer demand elasticities
- Estimate N, P, and K demand elasticities wrt prices
  - Crop prices and fertilizer prices drive application rates

\[- N_{ij} = N(p_{crops}, p_N, X) \]
\[- P_{ij} = P(p_{crops}, p_P, X) \]
\[- K_{ij} = K(p_{crops}, p_K, X) \]
Proposed Scenarios

• Fertilizer policy (tax?)
  – Possible result: yield reduction in the U.S. and land-use change elsewhere
Upgrades – Fertilizer Supply

• So far, a horizontal supply is assumed
  – Implies no change in fertilizer prices as demand changes

• We introduce a supply curve at the world level
Upgrades – Fertilizer Supply

• Supply curve
  – Short run: capacity constrained (less elastic)
  – Long run: capacity building (more elastic)

• Equation:

• Challenging: some fertilizer products are feedstocks of other (& self) industries. Must be taken into account
Upgrades – Fertilizer Supply

• Two main implications
• Fertilizer prices will adjust to demand changes
  – Nutrient price projections at the country level
  – Improved assessment of the cost of production in each crop yield equation

• Interaction with the FAPRI model
  – Each iteration of the FAPRI model will require to “pass” through the WorldNPK model
  – Changes in fertilizer prices update each run of the FAPRI model
Upgrades – Fertilizer Supply

• Data requirements:

• Production of fertilizer (IFA data)
  – By N, P & K products
  – By country

• Production capacity of fertilizer (IFA data)
  – Surveys on existing capacities
  – Surveys on projected capacity building
  – By nutrient & by major producing countries
  – About 10 years of data (2006 – 2015)

• Fertilizer prices
Upgrades – Fertilizer Supply

• IFA data on Production Capacity
  – Nitrogen products
    • Ammonia 2006 – 2015
    • Urea 2006 – 2015
    • Urea Ammonium Nitrate 2006 – 2015
    • Ammonium Nitrate 2004 – 2013
  – Phosphorous products
    • Processed Phosphates 2007 – 2015
    • Single Superphosphate 2004 – 2012
  – Potassium products
    • Potash 2007 – 2014