The Future of Agricultural Trade Policy Modeling: Insights from Meta-Analysis

Sebastian Hess & Stephan von Cramon-Taubadel
Georg-August University, Göttingen
1. Background and motivation

“Abolishing all trade barriers could boost global income by $US2.8 trillion and lift 320 million people out of poverty by 2015.”

M. Moore, Director-General, WTO 2002

“I am confident that I can concoct a model to generate any result desired by a reader with a deep pocketbook.”

J. Markusen
1. Background and motivation

• Quantitative models are arguably the single most visible input into trade policy debates that economists provide.

• However, quantitative models are frequently criticised:
  – Weak empirical and theoretical foundations
  – Complexity, ‘black-box’ character
  – Results vary widely even across similar experiments
1. Background and motivation

- Harbinson proposal (disproportionate reduction in high tariffs)
- 50% reduction in agricultural tariffs and export
- 100% reduction in agricultural tariffs and export subsidies

CATPRN Workshop. Toronto, February 9, 2008
1. Background and motivation

This:
→ is confusing for policy makers
→ is water on the mills of those who question liberalisation
→ reflects poorly on our credibility as a profession

Goal: To identify characteristics of simulations that systematically influence results, and to derive quantitative estimates of these influences
Outline

1. Background and motivation
2. What drives model simulation results?
3. Meta analysis
   • with a literature sample
   • with synthetic data
4. Conclusions
2. What drives simulation results?

\[ I = f\{ MC, LE, DB, RC \} \]

where:

\[ I \] = simulated impact of the liberalisation experiment

\[ MC \] = a vector of model characteristics

\[ LE \] = the nature of the liberalisation experiment

\[ DB \] = the database employed

\[ RC \] = the research context
2. What drives simulation results?

Modellers are, of course, aware of these issues:

1. Sensitivity analysis
   - Usually uni- or bi-variate
   - Propensity to document ‘robustness’

2. Qualitative review
   - Subjective selection of studies for analysis
   - Again, not multivariate
3. Meta analysis

• Main uses:
  – Combining evidence to obtain more precise estimates of an effect size (e.g. Medicine, but also economics)
  – Evaluating methods: quantifying the share of variance in a given set of estimates that is due to differences in methods, assumptions and other factors

• \( I = f\{MC, LE, DB, (\not{RC}, u}\)
3. Meta-analysis: Literature sample

- Exhaustive literature search: 160 combinations of 10 ‘Doha’ and 16 ‘modelling’ keywords, 18 databases

- Result → 1200 studies

- Eliminating:
  - repetition and redundancies
  - studies that do not report welfare changes
  - studies that provide no information on the model used
    → 230 studies

- Eliminating:
  - studies that do not focus on Doha Round liberalisation
  - studies that do not document key model characteristics
    → 110 studies
3. Meta-analysis: Literature sample

- Studies/year - initial literature sample (n=230)
- Studies/year - final literature sample (n=110)
- Avg. welfare gain/simulation in the final sample

Avg. welfare gain (billion US$)

Studies/year (count)


Sep. 2003 Cancun MM
Nov. 2001 Doha MM
Dec. 2005 Hong Kong MM
3. Meta-analysis: Literature sample

• Each of the 110 studies produces an average of 53 individual observations → n = 5835

• $I$ = simulated Δwelfare in million US$ (dummies account for different measures)

• $MC$ = a vector of 23 model characteristics (e.g. CRTS vs. IRTS, size of Armingtons, etc.)

• $LE$ = a vector of 5 measures of the size of the simulated liberalisation (e.g. tariff reduction, reduction in NTBs, shift to blue box spending)

• $DB$ = a vector of 4 dummies (GTAP-4, GTAP-5, etc.)
3. Meta-analysis: Literature sample

• This set of explanatory variables is the result of a specification search using:
  – stepwise regression
  – regression trees
  – an earlier sample of 53 studies
  – roughly 150 potential explanatory variables

• Unweighted and weighted OLS used to account for different number of observations per study
3. Meta-analysis: Literature sample

**Results (1)**

- Standards of documentation and transparency in the modelling literature are low
- Not seldom that the authors of a simulation are unable, a few years later, to reconstruct exactly how it was produced
- Modelling community small:
  - 288 authors contribute to the 230 studies
  - 25 most frequent authors involved in 176 (76%) of these studies
3. Meta-analysis: Literature sample

Results (2)

• $R^2$ in unweighted regression 24%, in weighted 46%
• Signs and significance of coefficients robust
• Most coefficients have expected signs and plausible magnitudes, e.g.:
  – Larger liberalisation steps $\rightarrow$ larger welfare gains
  – Higher Armington elasticities $\rightarrow$ larger welfare gains
  – Shocks to technical change $\rightarrow$ larger welfare gains
# 3. Meta-analysis: Literature sample

<table>
<thead>
<tr>
<th></th>
<th>Dummies for model interactions</th>
<th>Coeff.</th>
<th>Std.err.</th>
<th>Signif.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dynamic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRTS/perfect comp.</td>
<td>Cap. fixed</td>
<td>Arm's high</td>
<td>12342</td>
<td>939</td>
</tr>
<tr>
<td></td>
<td>Cap. accum.</td>
<td>Arm's low</td>
<td>2106</td>
<td>723</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Arm's high</td>
<td>12290</td>
<td>707</td>
</tr>
<tr>
<td>IRTS/imperfect comp.</td>
<td>Cap. accum.</td>
<td>Arm's low</td>
<td>451</td>
<td>1102</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Arm's high</td>
<td>14483</td>
<td>1863</td>
</tr>
<tr>
<td><strong>Comparative static</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>CRTS/perfect comp.</td>
<td>Cap. accum.</td>
<td>Arm's low</td>
<td>4518</td>
<td>278</td>
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<tr>
<td></td>
<td></td>
<td>Arm's high</td>
<td>4708</td>
<td>830</td>
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<tr>
<td>IRTS/imperfect comp.</td>
<td>Cap. fixed</td>
<td>Arm's high</td>
<td>20746</td>
<td>4766</td>
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<tr>
<td></td>
<td>Cap. accum.</td>
<td>Arm's low</td>
<td>5717</td>
<td>555</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Arm's high</td>
<td>6090</td>
<td>2586</td>
</tr>
</tbody>
</table>
3. Meta-analysis: Literature sample

Problems

• Many important variables can only be captured as dummies
• Functional form, interaction terms
• Many studies cannot be included due to incomplete documentation
• DDA studies focus on a limited sub-set of the relevant variable space (e.g. mostly tariff reductions)

Therefore: Synthetic data
3. Meta-analysis: Synthetic data

<table>
<thead>
<tr>
<th>PE Model “GSIM”</th>
<th>Single Country CGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Francois&amp;Hall 2003)</td>
<td>(van der Mensbrugghe, 2000)</td>
</tr>
<tr>
<td>• Wheat</td>
<td>• Agriculture &amp; All other</td>
</tr>
<tr>
<td>• Canada, US, EU, ROW</td>
<td>• CAN &amp; ROW</td>
</tr>
<tr>
<td>• Data = GTAP-5</td>
<td>• SAM=GTAP-5</td>
</tr>
<tr>
<td>• Armington-style import differentiation</td>
<td>• Armington import substitution</td>
</tr>
<tr>
<td>• Bilateral trade flows and tariffs</td>
<td>• Import tariffs, export subsidies, MFN</td>
</tr>
<tr>
<td>• Elasticities: demand, supply, import substitution</td>
<td>• CES production, CET exp./dom., ELES</td>
</tr>
</tbody>
</table>

CATPRN Workshop. Toronto, February 9, 2008
3. Meta-analysis: Synthetic data

Step 1: Generate ‘random’ numbers for \( k \) factors in \( X_i \) (model input)

Step 2: Plug these numbers into the model and solve for \( I_i \)

Step 3: Save scenario results to database

Database: \( l_i; X_i \ i=1...n \)
3. Meta-analysis: Synthetic data

- Generalized Additive Model (GAM)

\[ g(m) = \beta X_{ji} + f_1(X_{mi}) + f_2(X_{li}, X_{li}) + \varepsilon \]

- parametric smooth functions, non parametric

- \[ g(m) = E\{I_{ij}\}, \varepsilon \sim N(0, \sigma^2) \], model selection according to \( R^2 \)

⇒ Detect functional forms, interactions of \( X \)
⇒ Interpretation: Linear framework
3. Meta-analysis: Synthetic data

Results (1)

<table>
<thead>
<tr>
<th>Model</th>
<th>GAM order</th>
<th>Linear (X+X)</th>
<th>GAM smooth</th>
<th>Linear Interaction (X*X)</th>
<th>Linear (X+X), (X*X), (X²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE GSIM Δ(CS+PS)</td>
<td>0.77</td>
<td>0.78</td>
<td>0.87</td>
<td>0.87</td>
<td></td>
</tr>
<tr>
<td>CGE Δreal GDP</td>
<td>0.49</td>
<td>0.55</td>
<td>0.80</td>
<td>0.70</td>
<td></td>
</tr>
</tbody>
</table>

(Recall: $R^2$ unweighted literature sample $\approx 24\%$)
### 3. Meta-analysis: Synthetic data

#### Results (2): SAM

<table>
<thead>
<tr>
<th></th>
<th>Agriculture</th>
<th>Others</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>7924 (-0.031)</td>
<td>23188 (0.015)</td>
<td>...</td>
</tr>
<tr>
<td>Others</td>
<td>18736 (-0.007)</td>
<td>464809 (0.001)</td>
<td>...</td>
</tr>
<tr>
<td>Labour</td>
<td>8424 (-0.024)</td>
<td>312781 (0.004)</td>
<td>...</td>
</tr>
<tr>
<td>Capital</td>
<td>6977 (-0.038)</td>
<td>213616 (0.003)</td>
<td>...</td>
</tr>
<tr>
<td>Income Tax</td>
<td>-2105 (0.101)</td>
<td>12695 (-0.000)</td>
<td>...</td>
</tr>
</tbody>
</table>

...
3. Meta-analysis: Synthetic data

Comparing PE and GE models

1. Separate equations:

\[ I_i^{GE} = \beta^{GE} X_i + \phi Z_i + u_i \]

\[ I_i^{PE} = \beta^{PE} X_i + \gamma W_i + v_i \]

2. Single equation, fixed effects:

\[ I_i = \beta X_i + \alpha \begin{cases} D = 0, \text{GE} \\ D = 1, \text{PE} \end{cases} + u_i \]

3. Single equation, imputed missing values, fixed effects:

\[ I_i = \beta X_i + \phi \begin{cases} Z_i, \text{GE} \\ \overline{Z}_i, \text{PE} \end{cases} + \gamma \begin{cases} \overline{W}_i, \text{GE} \\ W_i, \text{PE} \end{cases} + \alpha \begin{cases} D = 0, \text{GE} \\ D = 1, \text{PE} \end{cases} + u_i \]
3. Meta-analysis: Synthetic data

\[ I_i = \beta X_i + \phi \left( \frac{Z_i, GE}{\bar{Z}_i, PE} \right) + \gamma \left( \frac{W_i, GE}{\bar{W}_i, PE} \right) + \alpha \left( \begin{array}{c} D = 0, GE \\ D = 1, PE \end{array} \right) + u_i \]

- \( I_i = \Delta CS \) for PE model; \( = \Delta Utility \) for GE model
- \( R^2 = 0.77 \)
- Estimate of \( \alpha = 4.76 \) bill. US$ (Prob >|t| = 0.000)
4. Conclusions

- Meta-analysis provides important insights beyond conventional sensitivity analysis and qualitative comparisons of model results.
- Results with synthetic data confirm basic insights of literature data, but $R^2$ much higher.
- Importance of interactions between model characteristics and liberalisation experiments revealed by synthetic data.
- Armington elasticities – weak empirical and theoretical basis, powerful impact on results.
4. Conclusions

- First stab at assessing the impact of variations in base data (SAM)
- Indications that solvers can add considerable variability to simulation results
- Important: Our results do not point to the ‘true’ model
- Simulation results must be interpreted with great caution
- Document, document, document!
Thank you!
Literature search

- Exhaustive literature search: 160 combinations of 10 ‘Doha’ and 16 ‘modelling’ keywords, 18 on-line databases

Databases employed in the literature search

<table>
<thead>
<tr>
<th>AgEconSearch</th>
<th>COPAC</th>
<th>Econis</th>
</tr>
</thead>
<tbody>
<tr>
<td>EconLit</td>
<td>Google/Google Scholar</td>
<td>IBZ</td>
</tr>
<tr>
<td>JADE</td>
<td>JSTOR</td>
<td>KVK</td>
</tr>
<tr>
<td>OCLC Journal Articles ECO</td>
<td>OCLC Papers</td>
<td>OCLC Proceedings</td>
</tr>
<tr>
<td>OCLC World Cat</td>
<td>OLC</td>
<td>RePec Articles</td>
</tr>
<tr>
<td>RePec Working Papers</td>
<td>SSCI</td>
<td>WTO House Library</td>
</tr>
</tbody>
</table>
## Literature search

### Modelling keywords

<table>
<thead>
<tr>
<th>applied model</th>
<th>CGE</th>
<th>comput*</th>
<th>dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td>economy wide</td>
<td>equilibrium</td>
<td>forward* model</td>
<td>general model</td>
</tr>
<tr>
<td>global model</td>
<td>international model</td>
<td>mathemat*</td>
<td>multi commodity</td>
</tr>
<tr>
<td>multi region*</td>
<td>multi sector*</td>
<td>partial model</td>
<td>static</td>
</tr>
</tbody>
</table>

### Doha keywords

<table>
<thead>
<tr>
<th>doha agric* market*</th>
<th>doha develop*</th>
</tr>
</thead>
<tbody>
<tr>
<td>doha domestic support</td>
<td>export subsid*</td>
</tr>
<tr>
<td>doha fair trad*</td>
<td>doha food security</td>
</tr>
<tr>
<td>doha market access</td>
<td>doha market* trad*</td>
</tr>
<tr>
<td>doha non trade</td>
<td>doha trade distort*</td>
</tr>
</tbody>
</table>
## Fixed effects (bill. US$)

<table>
<thead>
<tr>
<th>Country/region</th>
<th>Fixed effect (std. error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACP (intercept)</td>
<td>-11.6 (1.5)</td>
</tr>
<tr>
<td>Australia</td>
<td>5.0 (1.2)</td>
</tr>
<tr>
<td>Canada</td>
<td>7.3 (0.9)</td>
</tr>
<tr>
<td>India</td>
<td>8.3 (0.8)</td>
</tr>
<tr>
<td>EU-25</td>
<td>14.9 (2.5)</td>
</tr>
<tr>
<td>USA</td>
<td>16.9 (2.2)</td>
</tr>
</tbody>
</table>