Measured Aggregate Gains from International Trade

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Introduction

- New micro-level data in international trade
- New trade models to explain facts and answer new questions
- Did this agenda shape answers to key “aggregate” questions?
  - Implications of structural models for welfare gains from trade
- This talk: measured aggregate gains from trade
Measured gains from trade in practice

- Empirical relationship between trade & real GDP
  - e.g. Frankel-Romer 1999, Rodriguez-Rodrik 2001, Feyrer 2009

- Aggregate productivity: role of reallocation between producers
  - e.g. Bernard and Jensen 1999, Pavnik 2002, Trefler 2004

- CPI bias due to increasing varieties and quality
  - e.g. Feenstra 94, Broda-Weinstein 06, Feenstra-Romalis 2012
Questions

- Impact of reduction in trade costs on aggregate productivity?
  - Sufficient statistics across models?
- Does CPI & real consumption capture welfare gains?
- Provide some answers within a class of baseline trade models
- Follow measurement procedures of BEA
- Kehoe-Ruhl (2010), Feenstra-Reinsdorf-Slaughter (2009), Burstein and Cravino (2013)
Roadmap

- Perfect competition and general production functions
  - Reductions in trade costs and aggregate productivity
  - Welfare, real consumption, real GDP

- “New” trade model: MC, endogenous varieties and quality
  - Sufficient statistics for aggregate productivity
  - Biases in consumption deflators vs. welfare price indices

- Quantitative applications, relate to empirical literature
Perfect competition and general production functions

- Country $i$ endowed with production technologies $z \in \Omega_i$
Perfect competition and general production functions

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- Feasible output, $y_{it}(z)$, inputs, $x_{it}(z)$, $\in Y_i(z)$
Perfect competition and general production functions

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- Feasible output, $y_{it}(z)$, inputs, $x_{it}(z)$, $\in Y_i(z)$
- Aggregate supply of inputs $X_{it} = \int_{\Omega_i} x_{it}(z) \, dz$, assume constant
Perfect competition and general production functions

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- One unit of output produced in $i$, $1/\tau_{int}$ units available in $n$
Perfect competition and general production functions

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- One unit of output produced in $i$, $1/\tau_{int}$ units available in $n$
- Equilibrium allocations maximize profits given prices

$$
\Pi_{it} = \max_{\{y_{in}(z), x_i(z)\}} \int_{\Omega_i} \sum_n p_{int}(z) y_{in}(z) / \tau_{int} - W_{it} x_i(z) \, dz
$$

subject to $\{\sum y_{in}(z), x_i(z)\} \in Y_i(z)$ for all $z$
Real GDP and Aggregate Productivity

\[ GDP_{it} = \int_{\Omega} \sum_{n} p_{int}(z) y_{int}(z) / \tau_{int} \, dz = W_{it} X_{it} + \Pi_{it} \]
Real GDP and Aggregate Productivity

- $GDP_{it} = \int_{\Omega_i} \sum_n p_{int}(z) y_{int}(z) / \tau_{int} \, dz = W_{it} X_{it} + \Pi_{it}$

- $d \log GDP_{it} = \sum_n \int_{\Omega_i} \lambda_{int_0}(z) (d \log p_{int}(z) - d \log \tau_{int}) \, dz$
  - $\lambda_{int_0}(z)$: revenue share at $t_0$
Real GDP and Aggregate Productivity

- \( GDP_{it} = \int_{\Omega} \sum_n p_{int}(z) y_{int}(z) / \tau_{int} \, dz = W_{it} X_{it} + \Pi_{it} \)

- \( d \log GDP_{it} = \sum_n \int_{\Omega} \lambda_{int_0}(z) (d \log p_{int}(z) - d \log \tau_{int}) \, dz \)
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- \( d \log PPI_{it} = \sum_n \int_{\Omega} \lambda_{int_0}(z) d \log \bar{p}_{int}(z) \, dz \)
Real GDP and Aggregate Productivity

\[ GDP_{it} = \int_{\Omega_i} \sum_n p_{int}(z) y_{int}(z) / \tau_{int} \, dz = W_{it} X_{it} + \Pi_{it} \]

\[ d \log GDP_{it} = \sum_n \int_{\Omega_i} \lambda_{int0}(z) \left( d \log p_{int}(z) - d \log \tau_{int} \right) \, dz \]

\[ \lambda_{int0}(z): \text{ revenue share at } t_0 \]

\[ d \log PPI_{it} = \sum_n \int_{\Omega_i} \lambda_{int0}(z) d \log \bar{p}_{int}(z) \, dz \]

\[ d \log RGDP_{it} = d \log GDP_{it} - d \log PPI_{it} \]
Real GDP and Aggregate Productivity

\[ GDP_{it} = \int_{\Omega_i} \sum_n p_{int}(z) \gamma_{int}(z) / \tau_{int} dz = W_{it} X_{it} + \Pi_{it} \]

\[ d \log GDP_{it} = \sum_n \int_{\Omega_i} \lambda_{int_0}(z) (d \log p_{int}(z) - d \log \tau_{int}) dz \]

\[ \lambda_{int_0}(z): \text{ revenue share at } t_0 \]

\[ d \log PPI_{it} = \sum_n \int_{\Omega_i} \lambda_{int_0}(z) d \log \bar{p}_{int}(z) dz \]

\[ d \log RGDP_{it} = d \log GDP_{it} - d \log PPI_{it} \]

\[ d \log A_{it} = \sum_n \int_{\Omega_i} \lambda_{int_0}(z) d \log \left( \frac{p_{int}(z)}{\tau_{int} \bar{p}_{int}(z)} \right) dz \]

Plus tariff revenues evaluated at constant prices
Real GDP and Aggregate Productivity

- \( GDP_{it} = \int_{\Omega_i} \sum_n p_{\text{int}} (z) y_{\text{int}} (z) / \tau_{\text{int}} \, dz = W_{it} X_{it} + \Pi_{it} \)

- \( d \log GDP_{it} = \sum_n \int_{\Omega_i} \lambda_{\text{int}_0} (z) (d \log p_{\text{int}} (z) - d \log \tau_{\text{int}}) \, dz \)
  - \( \lambda_{\text{int}_0} (z) \): revenue share at \( t_0 \)

- \( d \log PPI_{it} = \sum_n \int_{\Omega_i} \lambda_{\text{int}_0} (z) d \log \bar{p}_{\text{int}} (z) \, dz \)

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- Plus tariff revenues evaluated at constant prices
Trade Costs and Aggregate Productivity

\[ d\log A_{it} = \sum_n \int_{\Omega_i} \lambda_{int_0}(z) \, d\log \left( \frac{p_{int}(z)}{\tau_{int} \tilde{p}_{int}(z)} \right) \, dz \]

- Trade costs incurred abroad

\[ \tilde{p}_{int}(z) = p_{int}(z) / \tau_{int} \Rightarrow d\log A_{it} = 0 \]
Trade Costs and Aggregate Productivity

\[ d\log A_{it} = \sum_n \int_{\Omega_i} \lambda_{int_0}(z) \, d\log \left( \frac{p_{int}(z)}{\tau_{int} \bar{p}_{int}(z)} \right) \, dz \]

- Trade costs incurred abroad
  \[ \bar{p}_{int}(z) = \frac{p_{int}(z)}{\tau_{int}} \Rightarrow d\log A_{it} = 0 \]

- Intuition: $\Delta$ productivity $\approx \Delta$ profits at constant prices
  - Evaluated at initial prices, profits fall
  - Evaluated at final prices, profits rise
Trade Costs and Aggregate Productivity

\[
\frac{d \log A_{it}}{dt} = \sum_n \int_{\Omega_i} \lambda_{int_0}(z) d \log \left( \frac{p_{int}(z)}{\tau_{int} \bar{p}_{int}(z)} \right) dz
\]

- Trade costs incurred abroad
  \[\bar{p}_{int}(z) = \frac{p_{int}(z)}{\tau_{int}} \Rightarrow d \log A_{it} = 0\]

- Intuition: \(\Delta \) productivity \(\approx\) \(\Delta\) profits at constant prices
  - Evaluated at initial prices, profits fall
  - Evaluated at final prices, profits rise

- Trade costs incurred domestically
  \[\bar{p}_{int}(z) = p_{int}(z) \Rightarrow d \log A_{it} = -\sum_n \lambda_{int_0} d \log \tau_{int}\]

- Aggregate productivity only captures, to a first order, changes in the domestic production set
Baseline: Real Consumption and Welfare

- Real consumption: expenditures deflated by CPI

- **Benchmark assumptions**
  - Homothetic preferences
  - Set of available goods and product quality fixed over time

- Theoretical price index $\approx$ CPI

- Higher order terms from using fixed weights in CPI (substitution bias).
Real Consumption and Real GDP

- Abstract from other sources of final demand (e.g. investment)
- Real consumption \( \neq \) real GDP
  - trade imbalances
  - terms of trade
Real Consumption and Real GDP

- Abstract from other sources of final demand (e.g. investment)
- Real consumption ≠ real GDP
  - trade imbalances
  - terms of trade
- World as a whole is a closed economy

- Change in variable trade costs, up to first order:

\[
\sum_i E_{it_0} d\log RC_{it} = \sum_i GDP_{it_0}^E d\log RGDP_{it}^E
\]

\[
\frac{1}{E_{wt_0}} \sum_i GDP_{it_0}^E d\log RGDP_{it}^E = -\frac{1}{E_{wt_0}} \times \sum_i \sum_n \text{Exports}_{int_0} \times d\log \tau_{in}
\]

- Independent of where trade costs incurred
- World real GDP captures 1st order effects of Δτ on welfare
“New” trade model

- Linear production functions: \( y = zl \)
- Variable trade costs incurred by exporter, same % of price for all \( i, n \) producers
- CES aggregator, monopolistic competition, constant markups

\[
C_{nt} = \left[ \sum_i \int_{\Omega_{nt}} a_{int}(z)^{\frac{1}{\rho}} q_{int}(z)^{\frac{\rho-1}{\rho}} \, dz \right]^{\frac{\rho}{\rho-1}}
\]

- Endogenous \( \Omega_{int} \), labor fixed costs to sell per destination
- Endogenous \( a_{int}(z) \), labor cost \( h(z, a) \)
- Constant aggregate profits / value added (e.g. free entry)
Measured Aggregate Productivity

- **PPI non-quality adjusted prices:**
  \[
  \frac{p_{int}(z)}{p_{int-1}(z)} = \frac{\tau_{int}}{\tau_{int-1}} \frac{W_{it}}{W_{it-1}}
  \]

- \[
  \frac{PPI_{it}}{PPI_{it-1}} = \sum_n \bar{\lambda}_{int} \frac{\tau_{int}}{\tau_{int-1}} \frac{W_{it}}{W_{it-1}}
  \]
  
  - \(\bar{\lambda}_{int}\) revenue share of continuing goods

- \[
  \frac{A_{it}}{A_{it-1}} = \frac{VA_{it}}{VA_{it-1}} \frac{1}{PPI_{it}/PPI_{it-1}}, \quad VA_{it} = \bar{k}_i W_{it} L_{it}
  \]

  \[
  \frac{A_{it}}{A_{it-1}} = \frac{1}{\sum_n \frac{\tau_{int}}{\tau_{int-1}} \bar{\lambda}_{int}}
  \]
Measured Aggregate Productivity

- **PPI non-quality adjusted prices:**
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  \]
  \[
  \bar{\lambda}_{int} \text{ revenue share of continuing goods}
  \]

- \[
  \frac{A_{it}}{A_{it-1}} = \frac{VA_{it}}{VA_{it-1}} \frac{1}{PPI_{it}/PPI_{it-1}}, \quad VA_{it} = \bar{\kappa}_i W_{it} L_{it}
  \]

- \[
  \frac{A_{it}}{A_{it-1}} = \frac{1}{\sum_n \frac{\tau_{int}}{\tau_{int-1}} \bar{\lambda}_{int}}
  \]

- **PPI quality-adjusted prices:**
  \[
  \text{Same expression, up to } 1^{st} \text{ order, if } G \sim \text{Pareto}, \quad h = z^\eta a^\gamma
  \]
Aggregate productivity and reallocation

- Standard productivity accounting:

\[
\Delta A_i = \sum_{z \in Z_{cont}} \Delta \frac{rva_i(z)}{l_i(z)} \times \frac{l_i(z)}{L_i} + \sum_{z \in Z_{cont}} \frac{rva_i(z)}{l_i(z)} \times \Delta \frac{l_i(z)}{L_i}
\]

\[
+ \sum_{z \in Z_{entry}} \frac{rva_{it}(z)}{l_{it}(z)} \frac{l_{it}(z)}{L_{it}} - \sum_{z \in Z_{exit}} \frac{rva_{it-1}(z)}{l_{it-1}(z)} \frac{l_{it-1}(z)}{L_{it-1}}
\]

- Different variations of this decomposition, e.g. BJ 99 U.S., Pavnik 02 Chile, Trefler 04 Canada

- Periods of large trade growth, “Reallocation” term large
Aggregate productivity decomposition

- Three specifications

1. Melitz with endogenous quality and cutoffs (all terms active)
2. Melitz with fixed quality and cutoffs (exit = 0)
3. Krugman (all firms the same, reallocation = 0)

- Two countries, trade shares 7% and 15%, trade elasticity = 3.5 (in i and iii), firm-size slope coefficient = 1.2, elasticity of exporters’ quality to trade costs = 1.3 (in i)
- \( \tau_t / \tau_{t-1} = 0.8 \), trade volumes roughly double
# Aggregate productivity decomposition

<table>
<thead>
<tr>
<th></th>
<th>Krugman</th>
<th>Melitz fixed</th>
<th>Melitz endog.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggr Prod. Fisher</td>
<td>0.26</td>
<td>0.20</td>
<td>0.26</td>
</tr>
<tr>
<td>Aggreg. product. $t_0 = 0$</td>
<td>0.15</td>
<td>0.16</td>
<td>0.16</td>
</tr>
<tr>
<td>% contribution:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>own</td>
<td>100%</td>
<td>94%</td>
<td>78%</td>
</tr>
<tr>
<td>reallocation</td>
<td>0</td>
<td>6%</td>
<td>99%</td>
</tr>
<tr>
<td>entry</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>exit</td>
<td>0</td>
<td>0</td>
<td>−77%</td>
</tr>
</tbody>
</table>

- Different composition, same total
  - Cannot conclude ↑ A smaller in absence of reallocation
Measured productivity and variable markups

\[
\frac{A_{it}}{A_{it-1}} = \frac{1 - \frac{\text{Prof}_{t-1}}{\text{VA}_{t-1}}}{1 - \frac{\text{Prof}_t}{\text{VA}_t}} \frac{1}{\sum_n \frac{\tau_{int}}{\tau_{int-1}} \frac{\overline{mkup}_{int}}{\overline{mkup}_{int-1}} \overline{\lambda}_{int}}
\]

- Reduction in Prof/VA reduces growth in measured productivity
  - Models in ACDR: Prof/VA unchanged
- Reduction in markups ↑ measured productivity
  - ↓ in trade costs: markups ↑ for exporters, ↓ for domestic
CPI versus Welfare-based price index

- So far, standard substitution bias
- New trade models:
  - Discontinued, newly produced, newly imported goods
  - Quality changes mismeasured in prices
- Next: CPI biases cancel-out, to a first order, at the world level
  - Country-by-country under stronger assumptions
  - With or without quality adjustment under stronger assumptions
Real consumption and welfare

- **Assumptions**
  - CES, CRS, \( \frac{\text{Profits}}{\text{VA}} \) constant, \( \frac{\text{trade cost}}{\text{price}} \) = all i,n producers

- **Change in variable trade cost, up-to first order:**

\[
\sum_i E_{it_0} d\log RC_{it} = \sum_i E_{it_0} d\log C_{it} = -\frac{1}{E_{wt_0}} \times \sum_i \sum_n \text{Exports}_{i n t_0} \times d\log \tau_{in}
\]

- **Envelope condition on firms’ exit, export, and quality**
  (Atkeson-Burstein 2010)
Real consumption and welfare: stronger assumptions

- Change in variable trade cost

- \( G \sim \text{Pareto and } h = z^n a^\gamma \)

  - World RC \( \cong \) theoretical consumption whether prices in CPI quality adjusted or not

- Fixed costs, quality costs incurred in destination markets, \( G \sim \text{Pareto}, h = z^n a^\gamma, \text{TB/GDP constant (ACR Prop 2)} \)

  - \( \Delta RC_i \cong \Delta \text{theoretical } C_i \)
Fixed and quality-related costs use domestic labor

<table>
<thead>
<tr>
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<th>$t_0 = 0$ wghts</th>
<th>$t_0 = 1$ wghts</th>
<th>Fischer</th>
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<tbody>
<tr>
<td>Small country</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>Large country</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>World</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
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<tr>
<td>Small country</td>
<td>0.16</td>
</tr>
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<td>Large country</td>
<td>0.07</td>
</tr>
<tr>
<td>World</td>
<td>0.10</td>
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Large uniform ↓ trade costs (doubling trade volumes)

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<tbody>
<tr>
<td>Small country</td>
<td>0.17</td>
<td>0.35</td>
<td>0.27</td>
</tr>
<tr>
<td>Large country</td>
<td>0.07</td>
<td>0.15</td>
<td>0.12</td>
</tr>
<tr>
<td>World</td>
<td>0.10</td>
<td>0.21</td>
<td>0.16</td>
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<tr>
<td>Large country</td>
<td>0.11</td>
</tr>
<tr>
<td>World</td>
<td>0.15</td>
</tr>
</tbody>
</table>

- Substitution bias more important than varieties, quality biases
Adjusting price indices for quality and variety

<table>
<thead>
<tr>
<th></th>
<th>Marginal ↓ $\tau$</th>
<th>Large ↓ $\tau$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Real consumption</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No adjustments</td>
<td>0.15</td>
<td>0.27</td>
</tr>
<tr>
<td>All quality adjustment</td>
<td>0.16</td>
<td>0.29</td>
</tr>
<tr>
<td>Imports variety adjusted</td>
<td>0.20</td>
<td>0.35</td>
</tr>
<tr>
<td>Imports variety &amp; quality adjustment</td>
<td>0.30</td>
<td>0.53</td>
</tr>
<tr>
<td><strong>Welfare</strong></td>
<td>0.16</td>
<td>0.26</td>
</tr>
</tbody>
</table>

- Measured real consumption closer to welfare if neither import nor domestic price indices adjusted for $\Delta$ in quality, variety
Taking stock

- **Aggregate productivity**
  - Captures shifts in domestic production possibility set, not changes in prices or trade costs incurred abroad
  - Sufficient statistics, different margins, same total

- **Consumption deflators versus welfare-based price index**
  - $\Delta$ variable trade cost: substitution bias more important than bias due to $\Delta$ varieties or mismeasured quality
  - Aggregate productivity captures 1st order effects of $\Delta \tau$ on welfare at world level, not country-by-country
  - Empirical link between trade and real GDP not likely to change much if consumption deflators used instead of output deflators, since these are highly correlated
Caution

- In using results on equivalence between RC and welfare to interpret in a welfare sense the observed relation between real consumption and trade in data.

- Many restrictions underlying our results may not be met in practice (e.g. changes in trade shares are not only driven by changes in variable trade costs).

- Our results establishing theoretical benchmark under which real consumption is a good measure of welfare in response to trade liberalization.

- Measurement procedures in individual countries may differ from US and recommended by UN.