Lecture 11: Trade, Welfare, Volatility

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Introduction

- Lectures 1-9:
  - Review the most important theoretical frameworks used to model international trade
  - Assess their capacity to predict international trade flows

- Can be used to answer broader economic questions:
  1. What is the impact of trade on welfare? (Lecture 10)
  2. What is the impact of specific experiments of trade liberalization?
  3. How does trade affect the organization of production processes?
  4. How much does trade spread the benefit of local improvements in technology?
  5. What is the impact of trade liberalization on domestic labor markets?
  6. How does specialization affect the volatility of GDPs?

- Today’s and next week’s classes will cover questions 2, 3 and 6
- Second semester’s course: Other “topics”
Today’s class

- Use Eaton & Kortum (2002) as a benchmark
- Enrich the benchmark model with as many properties as possible: Multiple sectors, IO linkages, NT good sectors, Exogenous shocks, etc.
- Calibrate the model to actual data / estimate the unobserved parameters
- Use the estimated model to run counterfactual analyses
- Advantage over alternative approaches (e.g., CGE models): Transparency + relatively parsimonious in terms of the required data (trade, sectoral production, tariffs, IO matrix)
Welfare Impact of Trade Liberalization
Trade and Welfare Impact of Trade Liberalization

- Caliendo & Parro (2015) build a Ricardian model to evaluate the trade and welfare impact of NAFTA

- NAFTA: A free trade area between the US, Mexico and Canada
  - Enhance trade within the area / Divert existing trade between the area and the RoW
  - Increase welfare: Access to cheaper consumption goods plus increased competitiveness through a drop in input prices
  - Potentially important Ricardian gains since the integrated countries have very different production structures

Main insights:
- Important role of sectoral IO linkages to amplify the trade and welfare effect of the partnership
Theoretical framework

i. Multiple sectors:

\[ U_i = \prod_{k=1}^{K} Q_i^k \alpha_i^k , \quad \sum_{k=1}^{K} \alpha_i^k = 1 , \quad Q_i^k = \left[ \int_0^1 Q_i^k(j) \frac{\sigma_{k-1}^{k-1}}{\sigma_k} \, dj \right] \frac{\sigma_k}{\sigma_{k-1}} \]

ii. Input-Output linkages:

\[ c_i^k = w_i^k \gamma_i^k \prod_{k' = 1}^{K} P_i^{k'} \gamma_i^{k',k'} , \quad \sum_{k=1}^{K} \gamma_i^{k,k'} = 1 - \gamma_i^k \]

iii. Non tradable sectors:

\[ d_{ni}^k = +\infty \text{ for some } k \]

iv. Sector-specific productivity distributions (Fréchet):

\[ F_i^k(z) = e^{-T_i^k z^{-\theta^k}} \]
Analytical predictions

- **Equilibrium prices under PC:**

  \[ p_{ni}(j) = \frac{c_i}{z_i^k(j)} d_{ni}^k \Rightarrow P_n^k = A^k \left[ \sum_{h=1}^{l} T_h^k \left[ c_h d_{nh}^k \right]^{-\theta_k} \right]^{-1/\theta_k} \]

- **Expenditure shares:**

  \[ \pi_{ni}^k = Pr[p_{ni}(j) \leq \min_s\{p_{ns}(j); s \neq i\}] \]

  \[ = \frac{T_i^k \left[ c_i d_{ni}^k \right]^{-\theta_k}}{\sum_{h=1}^{l} T_h^k \left[ c_h d_{nh}^k \right]^{-\theta_k}} \]

  Changes in tariffs affect \( \pi_{ni}^k \) directly (through \( d_{ni}^k \)) and indirectly (through the price of inputs encapsulated in \( c_i^k \))

- **GE solution under the assumption of balanced trade at the world level (but country-specific trade deficits) gives the vector of equilibrium wages \( \mathbf{w} \) which is specific to a tariff vector**
Impact of trade liberalization

1. **Equilibrium in relative changes implies**:

\[
\ln \frac{\hat{w}_n}{\hat{P}_n} = - \sum_{k=1}^{K} \frac{\alpha_n^k}{\theta_n^k} \ln \hat{\pi}_{nn}^k - \sum_{k=1}^{K} \frac{\alpha_n^k}{\theta_n^k} \frac{1 - \gamma_n^k}{\gamma_n^k} \ln \hat{\pi}_{nn}^k - \sum_{k=1}^{K} \frac{\alpha_n^k}{\gamma_n^k} \ln \prod_{l=1}^{J} \left( \frac{\hat{P}_l^k}{\hat{P}_n^k} \right)^{\gamma_n^{l,k}}
\]

- **Final goods**
- **Intermediate goods**
- **Sectoral Linkages**

\[
\ln \hat{\pi}_{ni}^k = -\theta_n^k \left[ \ln \hat{c}_i^k + \ln \hat{d}_{ni}^k - \ln \hat{P}_n^k \right]
\]

where \( \hat{x} = x'/x \), \( \{\hat{c}_i^k\} \) and \( \{\hat{P}_n^k\} \) are non-linear functions of \( \{\hat{w}_n\} \) and \( \{\hat{d}_{ni}^k\} \).

2. **Impact of trade liberalization on real wages** can be summarized by the impact it has on domestic shares (\( \{\pi_{nn}^k\} \)) and sectoral price indices (\( \{P_n^k\} \)).
Impact of trade liberalization (ii)

- Trade liberalization increases real wages by reducing the sectoral shares of domestic consumption ($\ln \hat{\pi}_{nn}$), i.e.
  
  i. Giving consumers access to cheaper imported goods (See ARC if $\gamma_n^k = 1$, $\forall n, k$)

  ii. Reducing the cost of same sector imported inputs (Only role of intermediates if $\gamma_n^k \neq 1$ and $\gamma_n^{k,k} = 1 - \gamma_n^k$)

  iii. Reducing the cost of imported inputs for other sectors (when $\gamma_n^{k,k} \neq 1 - \gamma_n^k$)

- Note: Changes in real wages do not directly map into changes in welfare in this model because of trade deficits ($D_n$) and tariff revenues ($R_n$):

  $$\ln \hat{W}_n = \ln \frac{\hat{I}_n}{\hat{P}_n} = \frac{w_n}{I_n} \ln \frac{\hat{w}_n}{\hat{P}_n} + \frac{R_n}{I_n} \ln \frac{\hat{R}_n}{\hat{P}_n} + \frac{D_n}{I_n} \ln \frac{\hat{D}_n}{\hat{P}_n}$$
Welfare Impact

- Using the equilibrium conditions of the model:

\[
\ln \frac{\hat{I}_n}{\hat{P}_n} = \sum_{h=1}^{I} \sum_{k=1}^{K} \left( \frac{E_{hn}}{I_n} \ln \hat{c}_n^k - \frac{M_{nh}}{I_n} \ln \hat{c}_h^k \right) + \sum_{h=1}^{I} \sum_{k=1}^{K} \frac{d_{nh}^k M_{nh}^k}{I_n} \left( \ln \hat{M}_{nh}^k - \ln \hat{c}_h^k \right)
\]

Terms of trade

Volume of trade

- Terms of trade effect due to an increase in exporter prices relative to the change in importer prices
- Volume of trade effect due to the creation of additional trade flows following trade liberalization
Empirical strategy

- Calibration of the observed parameters:
  - $\{\pi_{ni}^k\}$ calibrated using trade and production data
  - $\{\alpha_i^k\}$ fitted to data on sectoral absorption
  - $\{\gamma_i^k\}$ and $\{\gamma_i^{k,k'}\}$ fitted to IO tables

- Estimation of the unobserved parameters $\{\theta^k\}$:

$$\ln \frac{X_{ni}^k X_{im}^k X_{mn}^k}{X_{in}^k X_{mi}^k X_{nm}^k} = -\theta^k \ln \frac{d_{ni}^k d_{im}^k d_{mn}^k}{d_{in}^k d_{mi}^k d_{nm}^k}$$

$$\ln d_{ni}^k = \ln(1 + \tau_{ni}^k) + \nu_{ni}^k + \mu_n^k + \delta_i^k + \varepsilon_{ni}^k, \quad \nu_{ni}^k = \nu_{in}^k$$

$$\Rightarrow \ln \frac{X_{ni}^k X_{im}^k X_{mn}^k}{X_{in}^k X_{mi}^k X_{nm}^k} = -\theta^k \ln \frac{(1 + \tau_{ni}^k)(1 + \tau_{im}^k)(1 + \tau_{mn}^k)}{(1 + \tau_{in}^k)(1 + \tau_{mi}^k)(1 + \tau_{nm}^k)} + \varepsilon_{nim}^k$$

Use sectoral bilateral trade and tariff data
Trade and Welfare Impact of Trade Liberalization

Trade and the Volatility of Economies

Source: Caliendo & Parro, 2015. The “99% sample” and “97.5% sample” drop from the estimation the smallest countries in each sector.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Full sample</th>
<th>99% sample</th>
<th>97.5% sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>8.11 (1.86)</td>
<td>9.11 (2.01)</td>
<td>16.88 (2.36)</td>
</tr>
<tr>
<td>Mining</td>
<td>15.72 (2.76)</td>
<td>13.53 (3.67)</td>
<td>17.39 (4.06)</td>
</tr>
<tr>
<td>Manufacturing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food</td>
<td>2.55 (0.61)</td>
<td>2.62 (0.61)</td>
<td>2.46 (0.70)</td>
</tr>
<tr>
<td>Textile</td>
<td>5.56 (1.14)</td>
<td>8.10 (1.28)</td>
<td>1.74 (1.73)</td>
</tr>
<tr>
<td>Wood</td>
<td>10.83 (2.53)</td>
<td>11.50 (2.87)</td>
<td>11.22 (3.11)</td>
</tr>
<tr>
<td>Paper</td>
<td>9.07 (1.69)</td>
<td>16.52 (2.65)</td>
<td>2.57 (2.88)</td>
</tr>
<tr>
<td>Petroleum</td>
<td>51.08 (18.05)</td>
<td>64.85 (15.61)</td>
<td>61.25 (15.90)</td>
</tr>
<tr>
<td>Chemicals</td>
<td>4.75 (1.77)</td>
<td>3.13 (1.78)</td>
<td>2.94 (2.34)</td>
</tr>
<tr>
<td>Plastic</td>
<td>1.66 (1.41)</td>
<td>1.67 (2.23)</td>
<td>0.60 (2.11)</td>
</tr>
<tr>
<td>Minerals</td>
<td>2.76 (1.44)</td>
<td>2.41 (1.60)</td>
<td>2.99 (1.88)</td>
</tr>
<tr>
<td>Basic metals</td>
<td>7.99 (2.53)</td>
<td>3.28 (2.51)</td>
<td>-0.05 (2.82)</td>
</tr>
<tr>
<td>Metal products</td>
<td>4.30 (2.15)</td>
<td>6.99 (2.12)</td>
<td>0.52 (3.02)</td>
</tr>
<tr>
<td>Machinery n.e.c.</td>
<td>1.52 (1.81)</td>
<td>1.45 (2.80)</td>
<td>-2.82 (4.33)</td>
</tr>
<tr>
<td>Office</td>
<td>12.79 (2.14)</td>
<td>12.95 (4.53)</td>
<td>11.47 (5.14)</td>
</tr>
<tr>
<td>Electrical</td>
<td>10.60 (1.38)</td>
<td>12.91 (1.64)</td>
<td>3.37 (2.63)</td>
</tr>
<tr>
<td>Communication</td>
<td>7.07 (1.72)</td>
<td>3.95 (1.77)</td>
<td>4.82 (1.83)</td>
</tr>
<tr>
<td>Medical</td>
<td>8.98 (1.25)</td>
<td>8.71 (1.56)</td>
<td>1.97 (1.36)</td>
</tr>
<tr>
<td>Auto</td>
<td>1.01 (0.80)</td>
<td>1.84 (0.92)</td>
<td>-3.06 (0.86)</td>
</tr>
<tr>
<td>Other Transport</td>
<td>0.37 (1.08)</td>
<td>0.39 (1.08)</td>
<td>0.53 (1.15)</td>
</tr>
<tr>
<td>Other</td>
<td>5.00 (0.92)</td>
<td>3.98 (1.08)</td>
<td>3.06 (0.83)</td>
</tr>
</tbody>
</table>

Test equal parameters \[ F( 17, 7294) = 7.52 \] \[ \text{Prob} > F = 0.00 \]

Aggregate elasticity 4.55 (0.35) 4.49 (0.39) 3.29 (0.47)
Counterfactual analysis

i. Introduce the change in the tariff structure from 1993 to 2005 between NAFTA members, fixing the tariff structure for the RoW unchanged

ii. Introduce the change in the tariff structure from 1993 to 2005 between NAFTA members, given the observed changes in the tariff structure for the RoW

iii. Introduce the observed changes in world tariff structure from 1993 to 2005, holding NAFTA tariffs fixed to the year 1993

ii.-iii. say something about the gains from world tariff reductions with and without NAFTA

Note: In principle, trade liberalization might also have an impact on trade deficits, which the model does not take into account (they are exogenous). This is a shortcoming of the analysis
Source: Caliendo & Parro, 2015. In 1993, sectoral tariff rates applied by Mexico, Canada and the US to NAFTA members were on average 12.5, 4.2 and 2.7%. By 2005, they dropped to almost zero between NAFTA members but tariffs that Mexico, Canada and the US applied to the RoW were on average 7.1, 2.2 and 1.7%, respectively.
The role of intermediate goods and sectoral linkages

- In 1993, the role of intermediate goods is already substantial...
  - Respectively 68, 61.5 and 64.6% of Mexico’s, Canada’s and the US imports from non-NAFTA countries were intermediate goods
  - Respectively 82.1, 72.3 and 72.8% of Mexico’s, Canada’s and the US imports from NAFTA countries were intermediate goods

- ... As is the extent of cross-sectoral linkages:
  - In the IO Tables, the mean share of own-sector inputs is around 15-20%
  - More than 70% of intermediate consumption is addressed to other sectors
  - Average share of tradables in the production of non-tradables is 23% for the US and 32% for Mexico / Average shares of non-tradables in the production of tradables are 34% for the US and 26% for Mexico
Welfare effect from NAFTA’s Tariff reductions

Table 2. Welfare effects from NAFTA’s tariff reductions

<table>
<thead>
<tr>
<th>Country</th>
<th>Total</th>
<th>Terms of trade</th>
<th>Volume of Trade</th>
<th>Real wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mexico</td>
<td>1.31%</td>
<td>-0.41%</td>
<td>1.72%</td>
<td>1.72%</td>
</tr>
<tr>
<td>Canada</td>
<td>-0.06%</td>
<td>-0.11%</td>
<td>0.04%</td>
<td>0.32%</td>
</tr>
<tr>
<td>U.S.</td>
<td>0.08%</td>
<td>0.04%</td>
<td>0.04%</td>
<td>0.11%</td>
</tr>
</tbody>
</table>

Source: Caliendo & Parro, 2015. Analysis holds RoW tariffs unchanged

- Mexico gains the most, both in terms of welfare and in terms of real wages
- Most important source of gains is increase in the volume of trade (mostly within NAFTA, while trade vis-à-vis the RoW decreases, trade diversion)
- US terms-of-trade improved (both vis-à-vis NAFTA members and the RoW)
- Welfare effects widely vary across sectors
Trade and Welfare Impact of Trade Liberalization

Trade and the Volatility of Economies

Trade effect from NAFTA’s Tariff reductions

Table 5. Trade effects from NAFTA’s tariff reductions

<table>
<thead>
<tr>
<th></th>
<th>Mexico</th>
<th>Canada</th>
<th>U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mexico’s imports</td>
<td>-</td>
<td>116.60%</td>
<td>118.31%</td>
</tr>
<tr>
<td>Canada’s imports</td>
<td>58.57%</td>
<td>-</td>
<td>9.49%</td>
</tr>
<tr>
<td>U.S.’s imports</td>
<td>109.54%</td>
<td>6.57%</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: Caliendo & Parro, 2015. Analysis holds RoW tariffs unchanged

- Large aggregate effects for all members
- Canada and the US increased a lot their imports from Mexico: role as a supplier of intermediates to NAFTA
- Strong impact on the specialization of countries: Mexico becomes more specialized
Specialization due to NAFTA

Table 6. Export shares by sector before and after NAFTA’s tariff reductions

<table>
<thead>
<tr>
<th>Sector</th>
<th>Mexico Before</th>
<th>Mexico After</th>
<th>Canada Before</th>
<th>Canada After</th>
<th>United States Before</th>
<th>United States After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>4.72%</td>
<td>3.03%</td>
<td>4.99%</td>
<td>5.04%</td>
<td>6.91%</td>
<td>6.35%</td>
</tr>
<tr>
<td>Mining</td>
<td>15.53%</td>
<td>7.85%</td>
<td>8.99%</td>
<td>8.96%</td>
<td>1.72%</td>
<td>1.52%</td>
</tr>
<tr>
<td>Manufacturing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food</td>
<td>2.33%</td>
<td>1.48%</td>
<td>4.82%</td>
<td>4.68%</td>
<td>5.09%</td>
<td>4.73%</td>
</tr>
<tr>
<td>Textile</td>
<td>4.42%</td>
<td>6.92%</td>
<td>1.05%</td>
<td>1.49%</td>
<td>2.68%</td>
<td>3.49%</td>
</tr>
<tr>
<td>Wood</td>
<td>0.59%</td>
<td>0.52%</td>
<td>8.12%</td>
<td>8.05%</td>
<td>2.02%</td>
<td>1.98%</td>
</tr>
<tr>
<td>Paper</td>
<td>0.62%</td>
<td>0.51%</td>
<td>8.34%</td>
<td>8.44%</td>
<td>4.99%</td>
<td>4.89%</td>
</tr>
<tr>
<td>Petroleum</td>
<td>1.62%</td>
<td>5.28%</td>
<td>0.59%</td>
<td>0.78%</td>
<td>4.30%</td>
<td>5.71%</td>
</tr>
<tr>
<td>Chemicals</td>
<td>4.40%</td>
<td>2.53%</td>
<td>5.58%</td>
<td>5.40%</td>
<td>10.00%</td>
<td>9.25%</td>
</tr>
<tr>
<td>Plastic</td>
<td>0.80%</td>
<td>0.48%</td>
<td>2.06%</td>
<td>2.06%</td>
<td>2.28%</td>
<td>2.43%</td>
</tr>
<tr>
<td>Minerals</td>
<td>1.32%</td>
<td>0.84%</td>
<td>0.81%</td>
<td>0.78%</td>
<td>0.94%</td>
<td>0.92%</td>
</tr>
<tr>
<td>Basic metals</td>
<td>3.24%</td>
<td>2.00%</td>
<td>10.29%</td>
<td>10.19%</td>
<td>3.05%</td>
<td>3.11%</td>
</tr>
<tr>
<td>Metal products</td>
<td>1.22%</td>
<td>1.03%</td>
<td>1.47%</td>
<td>1.53%</td>
<td>2.23%</td>
<td>2.59%</td>
</tr>
<tr>
<td>Machinery n.e.c.</td>
<td>4.30%</td>
<td>2.53%</td>
<td>4.69%</td>
<td>4.49%</td>
<td>10.37%</td>
<td>9.70%</td>
</tr>
<tr>
<td>Office</td>
<td>3.34%</td>
<td>5.07%</td>
<td>2.44%</td>
<td>2.54%</td>
<td>7.70%</td>
<td>7.29%</td>
</tr>
<tr>
<td>Electrical</td>
<td>20.79%</td>
<td>34.07%</td>
<td>2.50%</td>
<td>2.35%</td>
<td>6.07%</td>
<td>7.97%</td>
</tr>
<tr>
<td>Communication</td>
<td>8.57%</td>
<td>7.08%</td>
<td>3.11%</td>
<td>3.02%</td>
<td>7.19%</td>
<td>6.81%</td>
</tr>
<tr>
<td>Medical</td>
<td>2.48%</td>
<td>3.28%</td>
<td>0.98%</td>
<td>1.03%</td>
<td>5.16%</td>
<td>4.79%</td>
</tr>
<tr>
<td>Auto</td>
<td>16.43%</td>
<td>13.05%</td>
<td>24.42%</td>
<td>24.07%</td>
<td>8.20%</td>
<td>8.09%</td>
</tr>
<tr>
<td>Other Transport</td>
<td>0.28%</td>
<td>0.26%</td>
<td>3.21%</td>
<td>3.58%</td>
<td>7.32%</td>
<td>6.65%</td>
</tr>
<tr>
<td>Other</td>
<td>3.02%</td>
<td>2.20%</td>
<td>1.55%</td>
<td>1.52%</td>
<td>1.77%</td>
<td>1.74%</td>
</tr>
</tbody>
</table>

Normalized Herfindahl 0.092 0.138 0.083 0.081 0.042 0.040

Decomposition of trade and welfare effects

<table>
<thead>
<tr>
<th>Country</th>
<th>Welfare - One sector</th>
<th>Multi sector - No materials</th>
<th>Multi sector - No I-O</th>
<th>Imports growth from NAFTA members - One sector</th>
<th>Imports growth from NAFTA members - Multi sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mexico</td>
<td>0.41%</td>
<td>0.50%</td>
<td>0.66%</td>
<td>60.99%</td>
<td>88.08%</td>
</tr>
<tr>
<td>Canada</td>
<td>-0.08%</td>
<td>-0.03%</td>
<td>-0.04%</td>
<td>5.98%</td>
<td>9.95%</td>
</tr>
<tr>
<td>U.S.</td>
<td>0.05%</td>
<td>0.03%</td>
<td>0.04%</td>
<td>17.34%</td>
<td>26.91%</td>
</tr>
</tbody>
</table>

Source: Caliendo & Parro, 2015. Analysis holds RoW tariffs unchanged

- Welfare gains are always reduced in comparison to benchmark
- Trade in intermediates, Sectoral heterogeneity and Sectoral linkages all matter
Trade and the Volatility of Economies
Caselli et al. (2015) build a dynamic Ricardian model to evaluate the impact of trade on the volatility of the economy.

Argument:
- Trade might induce sectoral specialization which would increase the exposure of countries to sectoral shocks (↑ Volatility except if specialization in low-volatile sectors)
- Trade also offers additional opportunities of diversification (against country-specific shocks, across markets) (↓ Volatility)

Main insights:
- Tariffs reduction since the 70s has reduced volatility
- Diversification across countries is an important driver of decreased volatility
- Specialization does not always push volatility up
Theoretical framework

i. Multiple sectors + IO Linkages (Caliendo & Parro, 2015)

ii. Stochastic shocks to the sector- and country-specific TFP: $A_{it}^k$

iii. Frictions to the allocation of labor across sectors:

$$L_{it}^k = \int_0^1 l_{it}^k(j) dj$$

is determined ex-ante (maximizes the representative consumer’s expected value of utility) but $l_{it}^k(j)$ allocates across firms after the realization of shocks

iv. No intertemporal trade and no capital → A sequence of static equilibria
Solution in Autarky

- FOC of the ex-ante program ($u(C) = \ln C$):

$$\frac{L_{nt}^k}{L_{nt}} = E_{t-1} \left[ \frac{w_{nt}^k L_{nt}^k}{\sum_j w_{nt}^j L_{nt}^j} \right] = \alpha^k$$

- Consumption maximization:

$$Q_{nt}^k = \alpha^k \left( \frac{P_{nt}^k}{P_{nt}} \right)^{-1} Q_{nt} \quad \text{and} \quad Q_{nt}^k(j) = \left( \frac{p_{nt}^k(j)}{P_{nt}^k} \right)^{-\sigma} Q_{nt}^k$$

- Equilibrium prices:

$$p_{nt}^k(j) = B^k \frac{w_{nt}^k \gamma^k P_{nt}^{1-\gamma^k}}{A_{nt}^k z_{nt}^k(j)}$$, \quad B^k = \gamma^k - \gamma^k (1 - \gamma^k) \gamma^k - 1$$

$$P_{nt}^k = \xi B^k \frac{w_{nt}^k \gamma^k P_{nt}^{1-\gamma^k}}{A_{nt}^k T^k^{1/\theta}}$$, \quad \xi = \left[ \Gamma \left( \frac{1 - \sigma}{\theta} - 1 \right) \right]^{\frac{1}{1-\sigma}}$$

$$P_{nt} = \prod_k \alpha^{k-\alpha^k} P_{nt}^k \alpha^k$$
Solution in Autarky (2)

- **Demand for inputs**: 
  
  \[ I_{nt}^k(j) = \gamma^k \frac{p_{nt}^k(j)Q_{nt}^k(j)}{w_{nt}} \] 

  \[ w_{nt} L_{nt}^k = \gamma^k p_{nt}^k Q_{nt}^k \]

- **Output**: 
  
  \[ M_{nt}^k(j) = (1 - \gamma^j) \frac{p_{nt}^k(j)Q_{nt}^k(j)}{P_{nt}} \] 

  \[ P_{nt} M_{nt} = (1 - \gamma^k) P_{nt} Q_{nt}^k \]

- **Finally, real output**: 
  
  \[ Y_{nt} = \prod_{k=1}^k R_n^k \left( \frac{\alpha^k \gamma^k}{\sum_j \alpha^j \gamma^j} \right) A_{nt}^k \frac{\alpha^k}{\gamma^k} L_{nt} \]

  with \( R_n \) a constant
Solution with international trade

- Inputs can potentially be sourced from different countries:

\[
G_{nt}^k(p) = 1 - e^{-\Phi_{nt}^kp^{\theta}}, \quad \Phi_{nt} = \sum_m T^k_m \left( \frac{B^k w^k_{mt} \gamma^k P_{nt}^{1-\gamma^k} d_{mnt}^k}{A_{nt}^k} \right)^{-\theta}
\]

\[
\pi_{nmt}^k = T_n^k \left( \frac{B^k w^k_{nt} \gamma^k P_{nt}^{1-\gamma^k} d_{mnt}^k}{A_{nt}^k} \right)^{-\theta} \Phi_{mt}^k
\]

- Equilibrium prices:

\[
P_{nmt}^k(j) = B^k d_{nmt}^k w_{nt}^k \gamma^k P_{nt}^{1-\gamma^k} A_{nt}^k z_n^k(j), \quad B^k = \gamma^k - \gamma^k (1 - \gamma^k)^{\gamma^k - 1}
\]

\[
P_{nt}^k = \xi \Phi_{nt}^{k-1/\theta}, \quad \xi = \left[ \Gamma \left( \frac{1 - \sigma}{\theta} - 1 \right) \right]^{\frac{1}{1 - \sigma}}
\]

\[
P_{nt} = \prod_k \alpha^{k-\alpha^k} P_{nt}^k \alpha^k
\]
Solution with international trade (2)

- Market equilibria

\[ w_{nt}^k L_{nt}^k = \gamma^k \sum_{m=1}^J \left[ \alpha^k + \frac{1 - \gamma^k}{\gamma^k} \frac{w_{mt}^k L_{mt}^k}{w_{mt} L_{mt}} \right] w_{mt} L_{mt} \]

\[ w_{nt} L_{nt} = \sum_k w_{nt}^k L_{nt}^k \]

\[ \frac{L_{nt}^k}{L_{nt}} = E_{t-1} \left[ \frac{w_{nt}^k L_{nt}^k}{\sum_j w_{nt}^j L_{nt}^j} \right] \]

- Resolution: i) Given \( L_{nt}^j \), equilibrium conditions give prices and market shares as a function of \( Z_{nt}^k \equiv T_n^k \left[ L_{nt} \left( A_{nt}^k \right)^{1/\gamma^k} \right]^\gamma^k \theta \), the augmented productivity, ii) solve for the sectoral shares (expected value of sectoral VA shares)
Volatility and Trade

- Intuition using a one-sector EK model
- In autarky:
  \[
  \text{Var}(\hat{Y}_{nt}^a) = \frac{1}{(\gamma\theta)^2} \text{Var}(\hat{Z}_{nt})
  \]

  where \(\hat{x}_t \equiv d \ln x_t\)
- In the costless equilibrium:
  \[
  \text{Var}(\hat{Y}_{nt}) = \frac{1}{(\gamma\theta)^2} \left[ \left( \frac{s_n + \gamma\theta}{1 + \gamma\theta} \right)^2 \text{Var}(\hat{Z}_{nt}) \right]
  
  + \left( \frac{1}{1 + \gamma\theta} \right)^2 \sum_{m \neq n} s_m^2 \text{Var}(\hat{Z}_{mt})
  
  + 2 \frac{s_n + \gamma\theta}{1 + \gamma\theta} \frac{1}{1 + \gamma\theta} \sum_{m \neq n} \text{Cov}(\hat{Z}_{nt}, \hat{Z}_{mt})
  
  \]

  where \(s_n\) is the relative size of country \(n\), at the mean \(Z_{nt}\)
Volatility and Trade (2)

- With uncorrelated shocks and constant variances:

\[
\text{Var}(\hat{Y}_{nt}) = \frac{1}{(\gamma \theta)^2} \left[ \left( \frac{s_n + \gamma \theta}{1 + \gamma \theta} \right)^2 \sigma^2 + \left( \frac{1}{1 + \gamma \theta} \right)^2 \sum_{m \neq n} s_m^2 \sigma^2 \right]
\]

\[
< \text{Var}(\hat{Y}_{nt}^a)
\]

⇒ Diversification of risk across countries

- In general, impact of trade on volatility depends on:
  1. Extent of diversification towards low volatile, uncorrelated countries
  2. Volatility of comparative advantaged sectors
Empirical strategy

- Calibration of the observed parameters:
  - \( \{\alpha_k^k\} \) and \( \{\gamma_n^k\} \) fitted to data on sectoral absorption, value added and output
  - \( \theta \) and \( \sigma \) calibrated (\( \theta \in [2, 8], \sigma = 2 \))
  - \( \{d_{nmt}^k\} \) calibrated based on bilateral trade data (assuming \( d_{nmt}^k = d_{mnt}^k \)):
    \[
    d_{nmt}^k = \left( \frac{\pi_{nmt}^k \pi_{mnt}^k}{\pi_{nnt}^k \pi_{mmt}^k} \right)^{1/2\theta}
    \]
  - \( \{Z_{nt}^k\} \) calibrated using the (inverse of the) formula for \( \pi_{nmt}^k \), then filtered to remove the LR component and finally decomposed into sector- vs country-specific components using a factor model
Counterfactual analysis

i. Quantify the impact that changes in tariffs between 1972 and 2007 have had on the volatility of countries’ GDP

ii. Counterfactual volatility muting either the country- or the sector-specific sources of TFP shocks
Impact of tariff reductions on volatility

Table 1: Baseline and counterfactual change in volatility (measured as variance) under free trade. Baseline calibration with $\theta = 4$.

<table>
<thead>
<tr>
<th>Country</th>
<th>Benchmark volatility</th>
<th>Volatility absent sectoral shocks</th>
<th>Volatility at 1972s trade barriers</th>
<th>Volatility absent sectoral shocks, at 1972s trade barriers</th>
<th>Volatility change due to change in trade barriers (5)</th>
<th>Volatility change due to specialization (6)</th>
<th>Volatility change due to diversification (7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>0.00085</td>
<td>0.00081</td>
<td>0.00090</td>
<td>0.00090</td>
<td>-5.6%</td>
<td>4.8%</td>
<td>-10.4%</td>
</tr>
<tr>
<td>Austria</td>
<td>0.00023</td>
<td>0.00020</td>
<td>0.00037</td>
<td>0.00033</td>
<td>-37.5%</td>
<td>-3.5%</td>
<td>-34.0%</td>
</tr>
<tr>
<td>Belgium and Luxembourg</td>
<td>0.00035</td>
<td>0.00019</td>
<td>0.00046</td>
<td>0.00042</td>
<td>-92.4%</td>
<td>-4.8%</td>
<td>-87.5%</td>
</tr>
<tr>
<td>Canada</td>
<td>0.00019</td>
<td>0.00014</td>
<td>0.00040</td>
<td>0.00037</td>
<td>-53.0%</td>
<td>4.2%</td>
<td>-57.2%</td>
</tr>
<tr>
<td>China</td>
<td>0.00631</td>
<td>0.00581</td>
<td>0.00630</td>
<td>0.00582</td>
<td>0.2%</td>
<td>0.3%</td>
<td>-0.1%</td>
</tr>
<tr>
<td>Colombia</td>
<td>0.00113</td>
<td>0.00089</td>
<td>0.00106</td>
<td>0.00084</td>
<td>6.2%</td>
<td>1.3%</td>
<td>4.9%</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.00031</td>
<td>0.00013</td>
<td>0.00049</td>
<td>0.00032</td>
<td>-35.5%</td>
<td>5.5%</td>
<td>-41.0%</td>
</tr>
<tr>
<td>Finland</td>
<td>0.00038</td>
<td>0.00034</td>
<td>0.00046</td>
<td>0.00045</td>
<td>-16.3%</td>
<td>7.2%</td>
<td>-23.5%</td>
</tr>
<tr>
<td>France</td>
<td>0.00022</td>
<td>0.00012</td>
<td>0.00023</td>
<td>0.00014</td>
<td>-7.5%</td>
<td>4.1%</td>
<td>-11.6%</td>
</tr>
<tr>
<td>Germany</td>
<td>0.00028</td>
<td>0.00014</td>
<td>0.00029</td>
<td>0.00018</td>
<td>-5.3%</td>
<td>6.0%</td>
<td>-11.3%</td>
</tr>
<tr>
<td>Greece</td>
<td>0.00032</td>
<td>0.00023</td>
<td>0.00028</td>
<td>0.00022</td>
<td>13.9%</td>
<td>10.4%</td>
<td>3.5%</td>
</tr>
<tr>
<td>India</td>
<td>0.00087</td>
<td>0.00082</td>
<td>0.00115</td>
<td>0.00150</td>
<td>-45.7%</td>
<td>-2.9%</td>
<td>-42.7%</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.00078</td>
<td>0.00055</td>
<td>0.06890</td>
<td>0.06919</td>
<td>-98.9%</td>
<td>0.8%</td>
<td>-99.6%</td>
</tr>
<tr>
<td>Italy</td>
<td>0.00117</td>
<td>0.00099</td>
<td>0.00115</td>
<td>0.00010</td>
<td>12.4%</td>
<td>19.5%</td>
<td>-7.1%</td>
</tr>
<tr>
<td>Japan</td>
<td>0.00027</td>
<td>0.00011</td>
<td>0.00025</td>
<td>0.00011</td>
<td>8.2%</td>
<td>7.4%</td>
<td>0.8%</td>
</tr>
<tr>
<td>Mexico</td>
<td>0.00066</td>
<td>0.00076</td>
<td>0.00186</td>
<td>0.00202</td>
<td>-64.3%</td>
<td>3.3%</td>
<td>-67.6%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.00021</td>
<td>0.00012</td>
<td>0.00239</td>
<td>0.00260</td>
<td>-91.4%</td>
<td>12.1%</td>
<td>-103.5%</td>
</tr>
<tr>
<td>Norway</td>
<td>0.00055</td>
<td>0.00046</td>
<td>0.01116</td>
<td>0.01078</td>
<td>-95.1%</td>
<td>-2.7%</td>
<td>-92.4%</td>
</tr>
<tr>
<td>Portugal</td>
<td>0.00115</td>
<td>0.00082</td>
<td>0.00193</td>
<td>0.00170</td>
<td>-40.3%</td>
<td>5.4%</td>
<td>-45.6%</td>
</tr>
<tr>
<td>ROW</td>
<td>0.00164</td>
<td>0.00173</td>
<td>0.00163</td>
<td>0.00173</td>
<td>0.6%</td>
<td>0.8%</td>
<td>-0.2%</td>
</tr>
<tr>
<td>South Korea</td>
<td>0.00094</td>
<td>0.00069</td>
<td>0.00097</td>
<td>0.00072</td>
<td>-3.3%</td>
<td>-0.9%</td>
<td>-2.4%</td>
</tr>
<tr>
<td>Spain</td>
<td>0.00018</td>
<td>0.00015</td>
<td>0.00017</td>
<td>0.00016</td>
<td>9.3%</td>
<td>14.7%</td>
<td>-5.4%</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.00020</td>
<td>0.00020</td>
<td>0.00030</td>
<td>0.00029</td>
<td>-32.7%</td>
<td>-2.1%</td>
<td>-30.6%</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>0.00020</td>
<td>0.00016</td>
<td>0.00020</td>
<td>0.00018</td>
<td>0.4%</td>
<td>9.2%</td>
<td>-8.8%</td>
</tr>
<tr>
<td>United States</td>
<td>0.00028</td>
<td>0.00017</td>
<td>0.00027</td>
<td>0.00018</td>
<td>2.1%</td>
<td>3.2%</td>
<td>-1.1%</td>
</tr>
<tr>
<td>Average</td>
<td>0.00075</td>
<td>0.00063</td>
<td>0.00429</td>
<td>0.00420</td>
<td>-26.8%</td>
<td>4.1%</td>
<td>-31.0%</td>
</tr>
</tbody>
</table>

Note: Column (1) shows the average volatility in the baseline model using the calibrated kappas and shocks from 1972-2007. Column (2) is the volatility in (1) after removing common sectoral shocks. Column (3) shows the average volatility using the calibrated shocks from 1972-2007 under the assumption that trading costs in manufacturing and agriculture remain at their 1970 levels. Column (4) is similar to (3), after removing common sectoral shocks. Column (5) shows the percent change in average volatility as economies lowered their trading costs (move from (3) to (1)). Column (6) shows the contribution of specialization to the change in volatility in (5). Column (7) shows the contribution of diversification to the change in volatility in (5).
Impact of tariff reductions on volatility (2)

- Two thirds of the countries experienced a ↓ in volatility (>90% for Bel-Lux, IRL, NLD, NOR)
- Diversification channel contributes to reducing Var in 90% of countries
- Specialization channel contributes to increasing Var in 2/3 of countries
- Limits :
  - Mixed evidence that trade indeed reduces volatility
  - Quantitative analysis circumvent the problem of causal identification...
  - ... But is strongly dependent on the underlying assumptions
  - eg does not take into account granularity effects (di Giovanni and Levchenko, 2012)
Conclusion

- EK model can be used to run counterfactuals on various questions:
  - Spillover effects of China’s growth on the RoW (Hsieh & Ossa, 2011, di Giovanni et al, 2014)
  - Impact of trade with emerging countries on labour markets (Levchenko and Zhang, 2013)
  - Impact of trade on the skill premium (Burstein & Vogel, 2012 and Parro, 2013)
  - ...

- Some of these topics will be studied in the second semester’s course
References

- Caselli, Koren, Lisicky & Tenreyro, 2015, “Diversification through trade”, mimeo