14.582 International Trade II
Lecture 8: Firm Heterogeneity (Theory III)
Today’s Plan

1. Why Should We Care About Firm Dynamics?
2. A Dynamic Model of Firm-Level Export and Innovation
3. Analytical Results
4. Computational Results
1. Why Should We Care About Firm Dynamics?
Today we will follow Burstein and Melitz (2011) and study firm dynamics in response to trade liberalization.

**Question:** *Why is this interesting?* (Always a good question to ask)

**Three reasons:**

1. Firm level dynamics may generate very different paths for aggregate variables that we care about.
   - SS outcome can give a misleading picture of overall response: Long lasting dynamic adjustments lead to $\neq$ NPV measures.

2. Firm-level dynamics may be interesting per-se.
   - How key model “ingredients” interact to induce different firm responses over time.

3. Anticipation effects may be especially important w.r.t. trade policy.
Recent empirical work on producer-level responses to globalization documents how changes in aggregate trading environment impact the decisions of heterogeneous firms (or plants) to

- Export (and choice of export locations)
- Enter and exit
- Innovate and invest in R&D
- Adapt technology and mode of operation
  - International supply chain
  - Horizontal & vertical FDI

Motivates the design of models explaining the heterogeneous response of firms to trade liberalizations

- Capture the important composition effects for aggregate variables (trade flows, investment, ... , and ultimately welfare)
- ... and endogenous source of comparative advantage
A substantial portion of the theoretical literature in this area assumes:

- No firm dynamics (life cycle or idiosyncratic uncertainty)
- Stable aggregate environment
  - Implies producers’ choices regarding international market participation and technology do not change over time

More recently, empirical evidence has highlighted the importance of the time dimension for this joint decision:

- Dynamic interactions between these producer-level choices following a change in the aggregate trading environment
- Generates a continuous feedback loop (for example, between export status, innovation, and productivity)

Burstein and Melitz (2011) focus on these dynamic interactions
What Burstein and Melitz (2011) Do

- Focus on models that build on GE literature of firm productivity dynamics and add firm-level decisions regarding international market participation (typically an export decision)

- Specifically examine the predictions for the dynamic responses to trade liberalization involving the following firm decisions:
  - Entry/exit, export, and innovation

- Analyze how firm dynamics and endogenous innovation give rise to aggregate transition dynamics (consumption, trade volumes, productivity) in response to trade liberalization
  - How does timing of trade liberalization matter?
    - Permanent versus temporary
    - Unanticipated versus anticipated

- They develop theoretical and computational models of firm dynamics, innovation, and international trade to answer these questions
Background (I): Theory

- Aggregate models of firm dynamics
- Firm dynamics and international trade
- Models of innovation by incumbent firms
- Static models of innovation by incumbents and international trade
- Models of innovation, firm dynamics and international trade
Background (II): Empirics

- **Hysteresis effects:**

- **Response of productivity/innovation to trade liberalization**
  - Lileeva & Trefler (2009) for Canada; Verhoogen (2009) for Mexico; and Bustos (2010) for Argentina; Aw, Roberts & Xu (2010) for Taiwan; Bloom et al. (2009) for competition from Chinese imports

- **Market demand dynamics**

- **Anticipation effects ahead of changes in trade costs**
  - Das et al. (2007): Effects of anticipated changes in exchange rates in some sectors
  - Bergin & Lin (2010): Entry into export markets ahead of EMU
  - Vanbeveren & Vandenbussche (2010): Increased firm innovation ahead of entry into new export markets
2. A Dynamic Model of Firm-Level Export and Innovation
Model Overview

- 2 country symmetric model with no aggregate uncertainty (no terms of trade or current account dynamics)
- Common CES product differentiation across all products (in both countries)
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• Heterogeneous firms stemming from firm-specific factor $z$ (productivity, loosely defined)
  • Entry subject to sunk cost
  • Firm productivity $z$ then evolves stochastically
  • Firms can influence this evolution process via innovation
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- Monopolistic competition: no strategic interactions
- Focus on entry and innovation (which determine distribution of firms) as only source of endogenous dynamics
Preferences

- Consumption index $C_t$ is CES aggregate of all available varieties (domestic and imported)
  - Symmetric elasticity of substitution $\rho > 1$
  - In equilibrium, this is also the value of aggregate production $Y_t$
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  - Let $P_t$ denote the CES price index of consumption
- Inter-temporal preferences of representative household given by:
  \[ U = \sum_{t=0}^{\infty} \beta^t \log(C_t) \]
  where $\beta \in (0, 1)$ is standard discount factor
- Equilibrium interest rate is determined by these intertemporal preferences:
  \[ R_t = \frac{1}{\beta} \frac{C_{t+1}}{C_t} \]
  (no aggregate uncertainty so perfect foresight)
Labor is only factor of production (and numeraire)

Each firm produces a separate differentiated variety

Firm hires $l_t(z)$ production workers (in addition to overhead labor $f$) and produces output:

$$y_t(z) = \exp(z)^{1/(\rho-1)}l_t(z).$$

so productivity $z$ indexes log differences in firm size (in equilibrium)

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Increasing returns to scale driven by fixed costs

A firm chooses to export to symmetric market subject to trade costs:

- Per-unit “iceberg” cost $\tau > 1$
- Per-period fixed cost $f_X$
- Later on, will also add a sunk cost $f_{EX}$
Monopolistic competition: firms sets price in domestic market at constant markup over marginal cost:

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Define the market demand index:

\[ \Pi_{dt} \equiv \frac{P_t^\rho Y_t}{\rho^\rho (\rho - 1)^{1-\rho}} \]

Then a firms total profits are given by:

\[ \Pi_t(z) = \Pi_{dt} \exp(z) - f + x_t(z) \left[ \Pi_{dt} \tau^{1-\rho} \exp(z) - f_X \right] \]

where \( x_t(z) \in \{0, 1\} \) represents an indicator variable for firm \( z \)'s export status.
Productivity Dynamics

- Exogenous exit with probability $\delta$ (independent of firm productivity $z$)
- Productivity evolution:
  - Conditional on survival, productivity $z$ can go up or down by an exogenous amount $\Delta z$
    - It increases to $z + \Delta z$ with probability $q$
    - It decreases to $z - \Delta z$ with probability $1 - q$
- No productivity dynamics: $\Delta z = 0$
Firms can affect this productivity evolution process via innovation, which affects the probability $q$

The investment cost of a given probability $q$ is $\exp(z) \, c(q)$ (in units of labor)

where $c(q)$ ($c_q > 0$, $c_{qq} > 0$) is the innovation cost function common across firms
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- Same innovation decision by large firms: $\bar{q}_t = \lim_{z \to \infty} q_t(z)$

Exogenous innovation is obtained from very steep innovation cost function such that $q_t(z) = \bar{q}$, $\forall z, t$. 
Exit

- The exit decision is determined by the maximization of overall firm value:

\[ V_t(z) = \max [0, V_t^o(z)] \]

which implies an exit cutoff \( \bar{z}_t \) such that \( V_t(\bar{z}_t) = 0 \)
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Entry

- Firms pay sunk investment cost \( f_E \) to enter (in units of labor)
  - ... then draw their initial \( z \) from a common distribution \( G(z) \) (potentially degenerate)
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Entry

- Firms pay sunk investment cost \( f_E \) to enter (in units of labor)
  - ... then draw their initial \( z \) from a common distribution \( G(z) \) (potentially degenerate)
- No other restrictions to entry, thus free-entry condition:

\[ \frac{1}{R_t} \int V_{t+1}(z) G(z) \, dz \leq f_E \]

with equality if entry is strictly positive
Parametrization: Innovation Cost Function

\[ c(q) = h \exp(bq) \]

- \( b = c''(q)/c'(q) > 0 \) indexes curvature of innovation cost function
- For exogenous innovation case, BM pick high enough \( b \) that all firms choose same innovation level \( q_t(z) = \bar{q} \)
For all cases with productivity dynamics, BM use degenerate distribution for entrants at \( z = 1 \).

BM calibrate \((h, f_X, \Delta z, \tau^{1-\rho}, \delta)\) to US data on (See Atkeson & Burstein 2010 for details):

- Firm employment-based size distribution.
- Variance of growth of large firms.
- Death of large firms.
- Exports / Gross Output.
- Share of employment in exporting firms.

Other parameters, do not affect calibration targets: \( \rho = 5, f, f_E \)

With Sunk Export Costs:

- Firms must pay additional sunk export cost \( f_{EX} \) to become exporters
  - Lose this investment if stop exporting
- BM assume that the majority of the fixed export costs are sunk, and calibrate \( f_{EX} \) to match the US data above.
Trade Liberalization Scenarios

- BM consider the effects of a 3.5% reduction in international per-unit trade costs $\tau$
- BM use this benchmark trade cost reduction throughout all scenarios
- BM first consider the effects of a permanent unanticipated reduction
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BM use this benchmark trade cost reduction throughout all scenarios

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BM then contrast this to:

- A temporary unanticipated reduction
- An anticipated (2 years prior) reduction (thereafter permanent)
- Similar anticipated reduction adding sunk export costs
3. Analytical Results
No Export Market Selection

- No fixed export cost $f_x = 0$
- With/without productivity dynamics (exogenous and endogenous innovation)
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Analytic results:
- Entry, exit, and innovation do not respond to changes in trade costs
  - Offsetting effects of increased export opportunities and reductions in domestic sales from imports, same for all producers
  - Hence adjust immediately to new steady state: no transition dynamics

\[
\left(1 + \tau' - \rho_1 + \tau_1 - \rho_1 \right) \rho - 1
\]

This is identical welfare gain as an Armington model (country produces a single good with exogenous unit labor requirement) and as in Krugman (1980)
No Export Market Selection

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- Steady state consumption gain is limited to direct effect of change in trade cost from \( \tau \) to \( \tau' \):

\[
\left( \frac{1 + \tau'^{1-\rho}}{1 + \tau^{1-\rho}} \right)^{\frac{1}{\rho-1}}
\]

- This is identical welfare gain as an Armington model (country produces a single good with exogenous unit labor requirement) and as in Krugman (1980)
No productivity dynamics, $\Delta z = 0$ (and hence no innovation)

Entering productivity $\exp(z)$ distributed Pareto with parameter $\theta > \rho - 1$
Export Market Selection But No Firm Productivity Dynamics

- No productivity dynamics, $\Delta z = 0$ (and hence no innovation)
- Entering productivity $\exp(z)$ distributed Pareto with parameter $\theta > \rho - 1$

Analytic results:

- Number of entrants does not depend on the trade cost in steady state (dynamic model extension of ACR)
- If trade costs fall, domestic cutoff rises, export cutoff falls
- Immediate transition to new steady state
  - Change in # of producers only comes from change in the cutoff
  - Here, there are composition effects. Note increasing domestic share of exporters and rise in average productivity
Let us now show how interaction of firm productivity dynamics and export market selection generates aggregate transition dynamics. These transition dynamics are generated by the response of entry to the change in the trade cost. In order to gain some intuition for the response of entry, BM start with a simplified version of their model.
Response of Entry to Trade Liberalization: Building Intuition

Consider the following simplified version of BM’s model:

- All firms have the same productivity level that is constant over time
- New entrants are non-exporters, exogenously become exporters when $T + 1$ periods old (and remain exporters thereafter)
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- Let \( s_x \) represent the aggregate share of exports in total sales (in the cross-section).
- Let \( \tilde{s}_x \) represent an entrant’s net present value of export sales relative to the net present value of total sales.

If \( T = 0 \) (all firms export) or \( \beta = 1 \) (no discounting), then \( s_x = \tilde{s}_x \). As \( T \) increases (it takes longer for an entrant to become an exporter) and \( \beta \) decreases (more discounting), then \( \tilde{s}_x \) decreases relative to \( s_x \): Profits from exporting become a less important component of a firm’s value upon entry.
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- Profits from exporting become a less important component of a firm's value upon entry.
Analytic results:

- When trade costs fall, entry falls (increases) in steady state if and only if $\bar{s}_x < s_x$ ($\bar{s}_x > s_x$)
- For a given small change in trade costs, the percentage change in entry is proportional to $\bar{s}_x - s_x$
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Intuition:

- When $\tilde{s}_x < s_x$, trade liberalization makes entry less profitable: Incumbent/exporters firms benefit proportionally more than entrants/non-exporters from lower trade costs
4. Computational Results
This same intuition applies to the full model with productivity dynamics and export market selection.

Following figure considers a parameterization of the model with exogenous productivity dynamics, in which entrants are less likely to export than incumbent firms (i.e. $\bar{s}_x < s_x$).
Calibrated Transition Dynamics

- Illustrate analytic result in following figure
  - Panel A reports $\tau_t/\tau_0$, Panels B-F report $\log(X_t/X_0)/\log(\tau_t/\tau_0)$ for each variable $X$
Permanent liberalization, exogenous innovation

Panel A: Trade cost, relative to pre-liberalization

Panel B: Final output (-), Production labor (--)

Panel C: Entry

Panel D: Average firm productivity

Panel E: Export/output (-), Domestic share of exporters (--)

Panel F: Process innovation intensity
Export Market Selection and Firm Productivity Dynamics

Summary

- Entry drops along transition and in new steady state
  - Trade liberalization makes entry less profitable: Incumbent/exporters firms benefit proportionally more than entrants/non-exporters
  - Mass of producing firms steadily decreases to its new steady state
Consider an alternative parametrization with *no discounting* \( (\beta = 1) \):
- Wait for entrant to become an exporter is now inconsequential.
- This increases the importance of the future expected exporting profits for an entrant.
  - Entry responds less negatively to trade liberalization.
Permanent liberalization, exogenous innovation, positive interest rate (-) and zero interest rate (--)
Following figure considers a parameterization of the model with \textit{endogenous innovation}
Permanent Liberalization: Endogenous Innovation

Panel A: Trade cost $\tau$, relative to pre-liberalization

Panel B: Final output $Y$ (\$), Production labor $LP$ ($\rightarrow$)

Panel C: Entry, ME

Panel D: Average firm productivity, $Zbar$

Panel E: Export share $sX$ (\$), Exporters domestic share $sD$ ($\rightarrow$)

Panel F: Innovation by large exporters, $q(z)$ high $z$
Innovation intensity by exporters rises

- Lower trade costs increase the value of exporters relative to non-exporters, and the former respond by innovating relatively more.
- Average firm productivity increases, driven by the productivity increase of exporters.
- Increase in relative size and productivity of exporters takes a long time to unfold.

Trade volumes relative to output steadily increases as exporters become relatively more productive.

- Short run elasticity of trade with respect to trade costs is substantially smaller than the long run elasticity.

Anticipation effects: Some non-exporters increase innovation in anticipation of future export status.

Why declining trend for entry: Increased innovation by exporters also implies that an entrant’s expected profits from exporting get pushed back even further into the future.
Export Market Selection and Firm Productivity Dynamics

Increased Innovation by Non-Exporters

Change in innovation intensity by firm across steady-states

- log change in innovation intensity $q(z)$
- initial export threshold
- new export threshold

$z - z_{exit \ threshold}$
For these endogenous changes in productivity and trade volumes (arising from changes in endogenous innovation) to be important, trade liberalization must be perceived to be long lasting.

Similarly, in model with sunk export costs, trade liberalization must be perceived to be long-lasting in order to provide incentives for firms to pay sunk export cost (see scenario 7 in paper).

The following figure considers a parameterization of the model with endogenous productivity dynamics:

- *Temporary reduction in trade costs* (see path of $\tau$ in Panel A)
Two key effects:

1. **Incentives:** Entry and innovation responses are forward looking
   - Permanence of trade liberalization affects incentives for entry and innovation
   - Innovation intensity by exporters rises by less when reduction in trade costs is temporary

Transition dynamics are slow: given incentives, changes in entry and innovation take a long time to unfold. As the time window for lower trade costs is reduced, the role of endogenous innovation becomes increasingly muted. The following figure shows that the differences between endogenous and exogenous innovation are very muted when trade liberalization is temporary.
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2. **Transition dynamics are slow**: given incentives, changes in entry and innovation take a long time to unfold
   - As time window for lower trade costs is reduced, the role of endogenous innovation becomes increasingly muted
   - The following figure shows that the differences between endogenous and exogenous innovation are very muted when trade liberalization is temporary
The following figure considers an anticipated, permanent reduction in trade costs (see path of $\tau$ in Panel A) in the parametrizations of the model with exogenous and endogenous innovation.

Anticipation effects for innovation: rise in innovation precedes reduction in trade costs if the latter is anticipated.
Anticipated Liberalization: Exogenous (-) and Endogenous (--) Innovation

Panel A: Trade cost, $\tau$

Panel B: Innovation by large exporters, $q(z)$ high $z$

Panel C: Exporters domestic share, $sD$

Exogenous innovation
Endogenous innovation
Anticipation effects for innovation: rise in innovation precedes reduction in trade costs if the latter is anticipated.

- Implies that the rise in share of exporters in domestic sales precedes the reduction in trade costs
- What has been viewed as “exogenous” differences in productivity driving export market selection can also have an endogenous component
Let us now introduce *sunk* costs of exporting, but stick to the case of *exogenous innovation*.

The following figure considers an anticipated, permanent reduction in trade costs.

- Contrast between fixed and sunk costs.
Anticipated Trade Liberalization, Exogenous Innovation, Fixed costs (-) and Sunk Export Costs (--)
Anticipation Effects: Sunk Costs and Option Values

Summary

- Uncertainty and sunk export costs generate option values, and anticipation effects of trade liberalization affects these option values ahead of actual changes in trade costs.
  - Implies that, with sunk export costs, the rise in share of exporters in domestic sales precedes the reduction in trade costs
Concluding Remarks

- Characterization of dynamic responses to trade liberalization in GE models of industry productivity dynamics with both endogenous innovation and trade
  - Can address recent evidence regarding firms’ response to liberalization over time
    - Including: entry/exit, export, and innovation decisions
- These decisions generate endogenous dynamics for aggregate productivity, trade volumes, and consumption
- Long lasting adjustment dynamics arise from combination of firm productivity dynamics and endogenous export market selection
- Timing of trade liberalization shape endogenous dynamics

Future work?

- Static models with firm-level heterogeneity useful to understand cross-sectional facts about labor markets
- Could we use models with firm-level dynamics to study transition dynamics in labor markets in response to trade liberalization?