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?

Motivation

- 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

Broad Research Agenda

- 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

Firm Dynamics Are Relevant for this Research Agenda

- 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
  - Hopenhayn (1992), Atkeson & Kehoe (2005), Luttmer (2007)
- Firm dynamics and international trade
  - Alessandria & Choi (2007), Arkolakis (2009), Irarrazabal & Opromolla (2009), Ruhl (2008), Ruhl & Willis (2008)
- Models of innovation by incumbent firms
  - Griliches (1979), Erikson & Pakes (1995), Klette & Kortum (2004)
- Static models of innovation by incumbents and international trade
  - Bustos (2007), Yeaple (2005)
- Models of innovation, firm dynamics and international trade
  - Constantini & Melitz (2008), Atkeson & Burstein (2010), Perla Tonetti & Waugh (2015), Sampson (2015)

Background (II): Empirics

- Hysteresis effects:
  - Roberts & Tybout (1997), Bernard & Jensen (2008)
- Response of productivity/innovation to trade liberalization
  - Lileeva & Trefler (2009) for Canada; Verhoogen (2009) for Mexico; and Bustos (2010) for Argentina; Aw, Robers & Xu (2010) for Taiwan; Bloom et al. (2009) for competition from Chinese imports
- Market demand dynamics
  - Eaton et al (2010)
- 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)
- Single factor of production: labor – inelastically supplied

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  - Entry subject to sunk cost
  - Firm productivity z then evolves stochastically
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  - Entry subject to sunk cost
  - Firm productivity z then evolves stochastically
  - Firms can influence this evolution process via innovation
- 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)

Production and Trade

- 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}

Static Profits

- 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 δ (independent of firm productivity z)
- Productivity evolution:
  - Conditional on survival, productivity z can go up or down by an exogenous amount Δ_z
    - It increases to $z + \Delta_z$ with probability q
    - It decreases to $z - \Delta_z$ with probability $1 - q$
  - No productivity dynamics: $\Delta_z = 0$

Innovation

- 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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- For a given q, the investment cost is proportional to a firm's size in its *domestic* market
  - This implies size-independent growth for large firms, consistent with Gibrat's law
  - Same innovation decision by large firms: $\bar{q}_t = \lim_{z \to \infty} q_t(z)$

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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 $q_t(z) = \bar{q}, \ \forall z, t$

Entry and Exit

Exit

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

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

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

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  - ... 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:

$$\frac{1}{R_t}\int V_{t+1}(z)\,G(z)\,\mathrm{d}z \leq f_E$$

  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 $q_t(z) = \bar{q}$

Parametrization: Remaining Calibration

- 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 τ
- BM use this benchmark trade cost reduction throughout all scenarios
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- BM use this benchmark trade cost reduction throughout all scenarios
- BM first consider the effects of a permanent unanticipated reduction
- 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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  - 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

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  - Hence adjust immediately to new steady state: no transition dynamics
- Steady state consumption gain is limited to direct effect of change in trade cost from τ to τ':

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

  - This is identical welfare gain as an Armington model (country produces a single good with exogenous unit labor requirement) and as in Krugman (1980)

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 $\theta > \rho - 1$

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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

Export Market Selection And Firm Productivity Dynamics

- 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 $\tilde{s}_x$ represent an entrant's net present value of export sales relative to the net present value of total sales

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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 β 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

Response of Entry to Trade Liberalization: Building Intuition

Analytic results:

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

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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

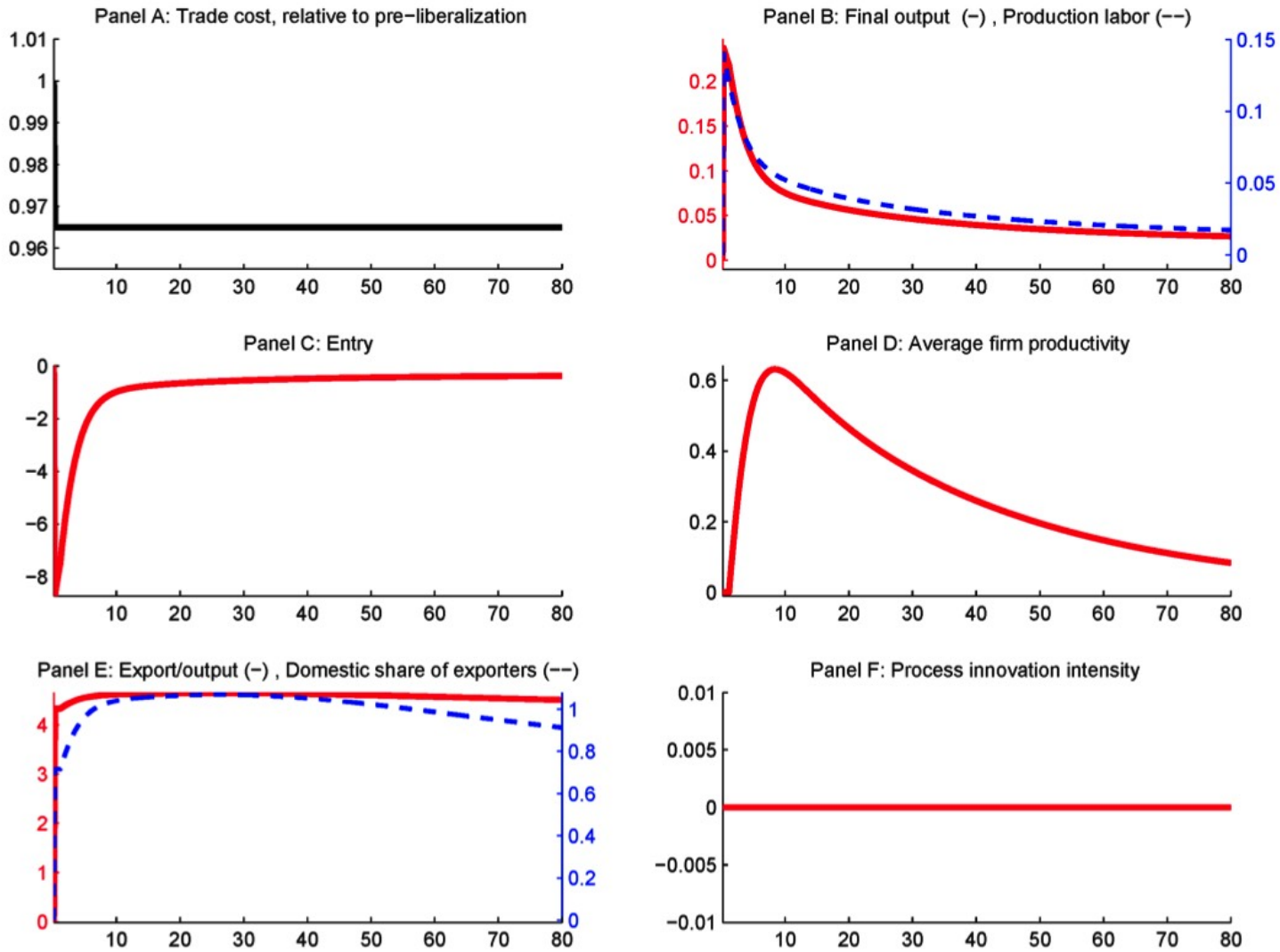
Export Market Selection and Firm Productivity Dynamics

- 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. $\tilde{s}_x < s_x$)

Calibrated Transition Dynamics

- Illustrate analytic result in following figure
  - Panel A reports τ_t / τ_0, Panels B-F report $\log(X_t / X_0) \,/\, \log(\tau_t / \tau_0)$ for each variable X

Permanent liberalization, exogenous innovation



Export Market Selection and Firm Productivity Dynamics

Summary

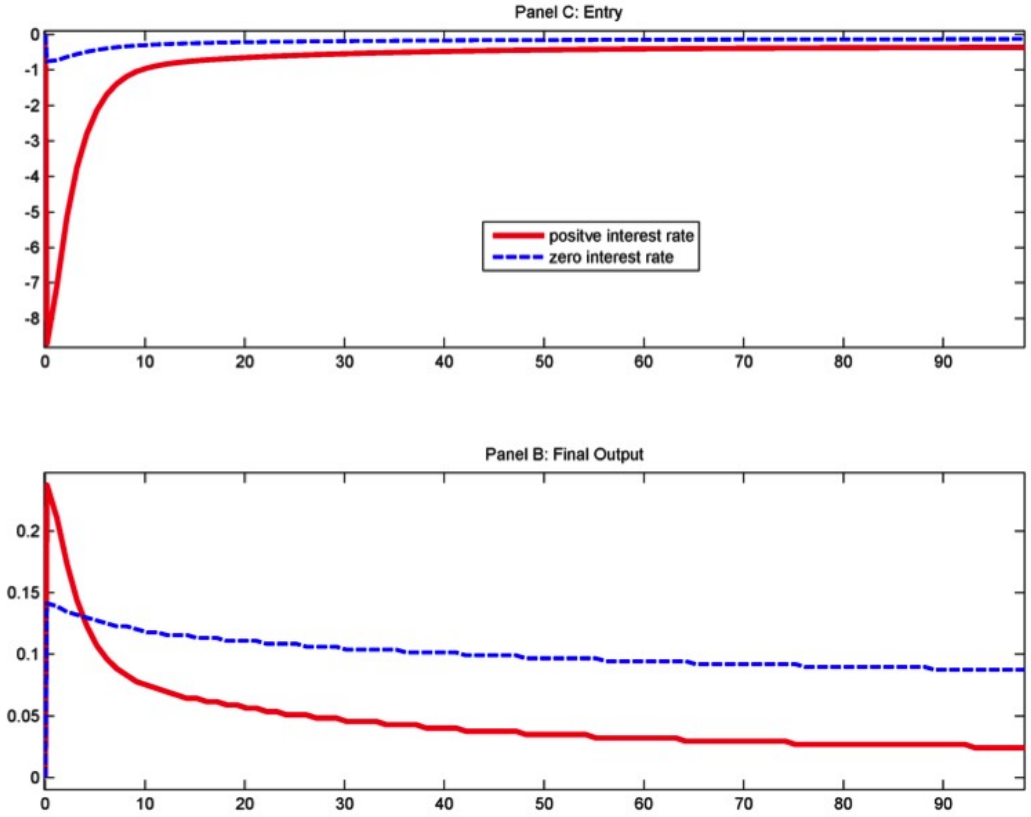
- Entry drops along transition and in new steady state
  - Trade liberalization makes entry less profitable: Incumbent/exporters firms benefit proportionally more than entrants/non-exporters
  - Mass of producing firms steadily decreases to its new steady state

Export Market Selection and Firm Productivity Dynamics

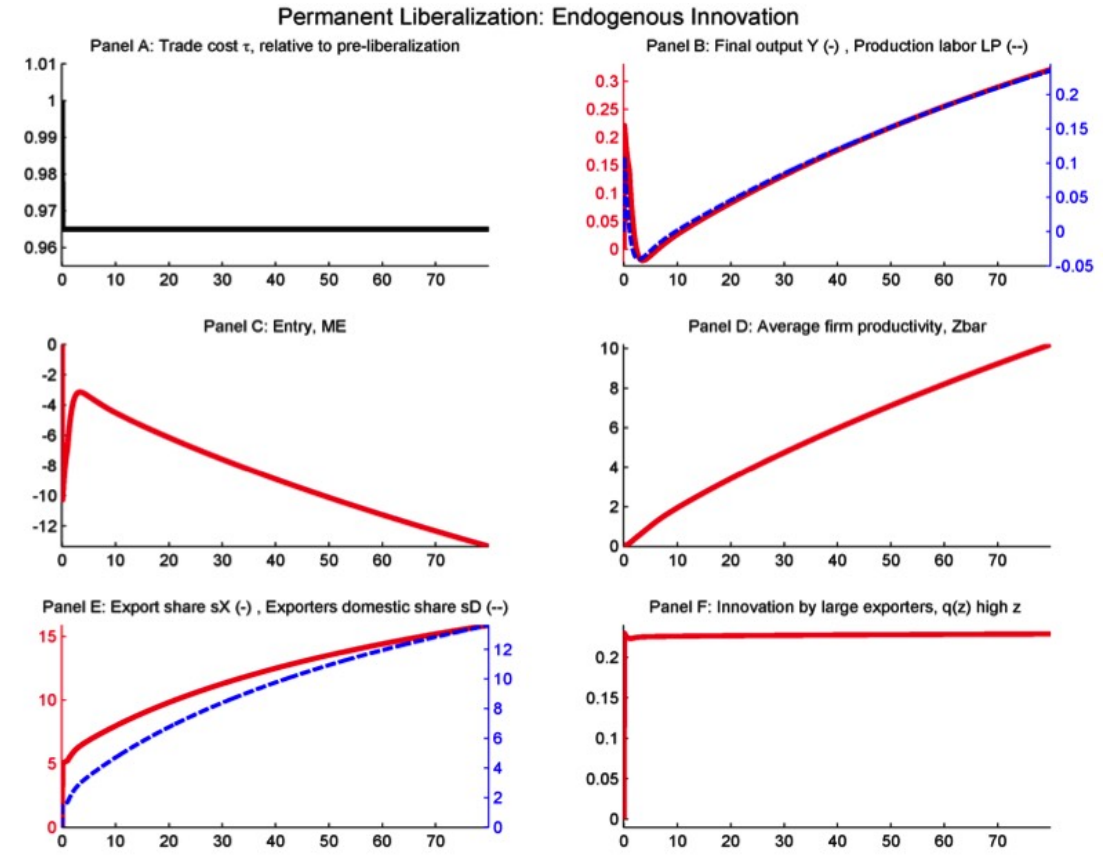
Alternative Parametrizations

- 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 *endogenous innovation*


Permanent Liberalization: Endogenous Innovation
Panel A: Trade cost τ, relative to pre-liberalization
Panel B: Final output Y (-) , Production labor LP (--)
Panel C: Entry, ME
Panel D: Average firm productivity, Zbar
Panel E: Export share sX (-) , Exporters domestic share sD (--)
Panel F: Innovation by large exporters, q(z) high z

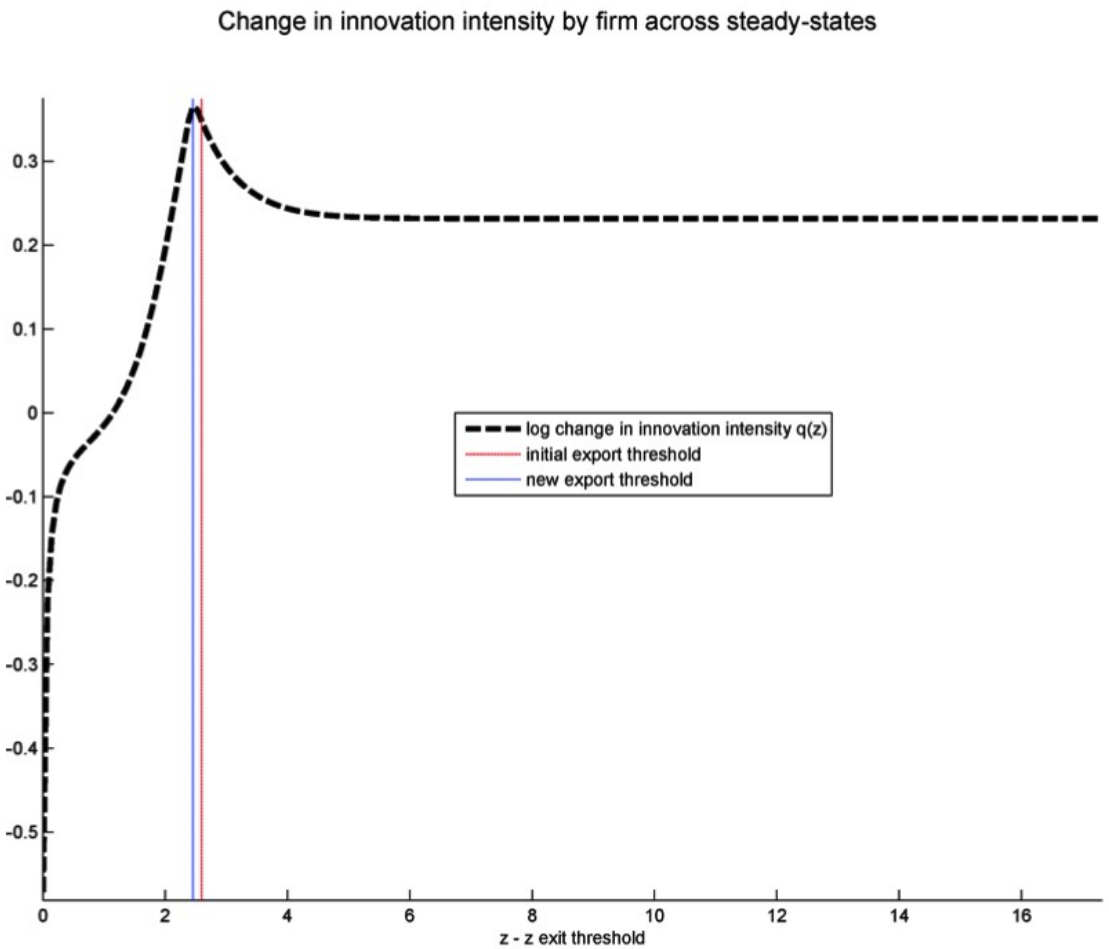
Export Market Selection and Firm Productivity Dynamics

Consequences of Endogenous Innovation

- 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

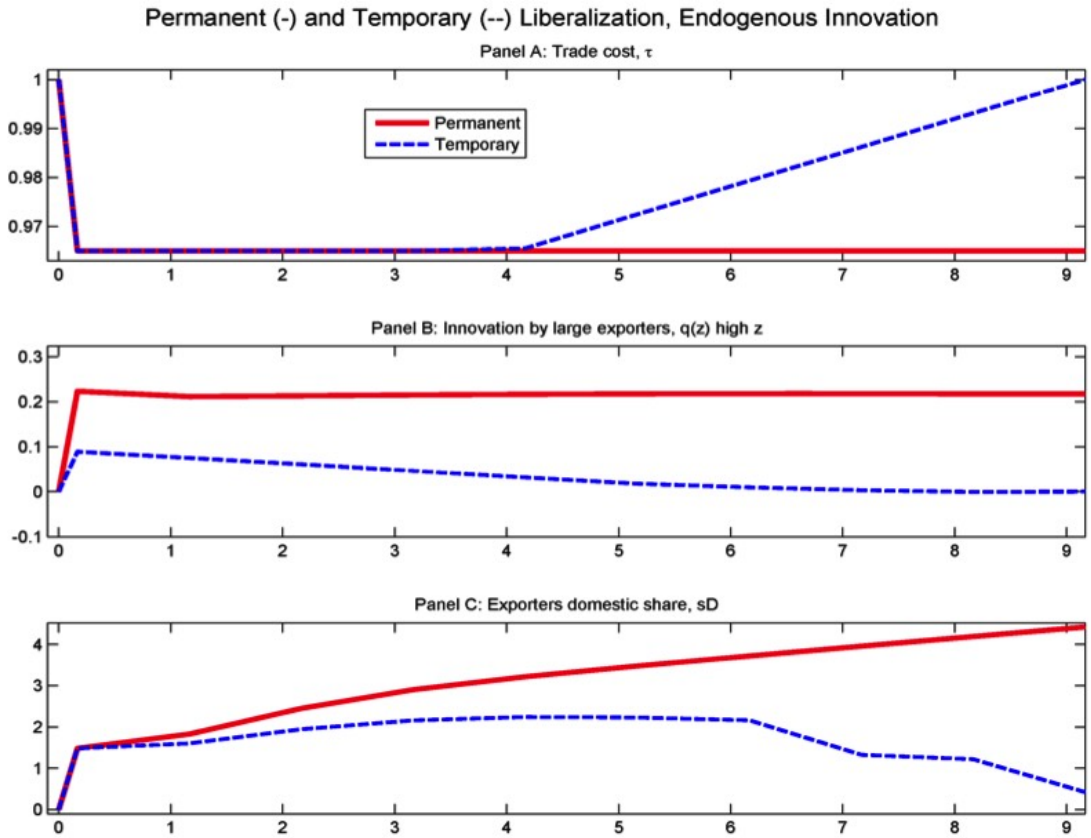
Export Market Selection and Firm Productivity Dynamics

Increased Innovation by Non-Exporters



Permanence of Trade Liberalization

- 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 τ in Panel A)


Permanent (-) and Temporary (--) Liberalization, Endogenous Innovation
Panel A: Trade cost, τ
Permanent
Temporary
1
0.99
0.98
0.97
0 1 2 3 4 5 6 7 8 9
Panel B: Innovation by large exporters, q(z) high z
0.3
0.2
0.1
0
-0.1
0 1 2 3 4 5 6 7 8 9
Panel C: Exporters domestic share, sD
4
3
2
1
0
0 1 2 3 4 5 6 7 8 9

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

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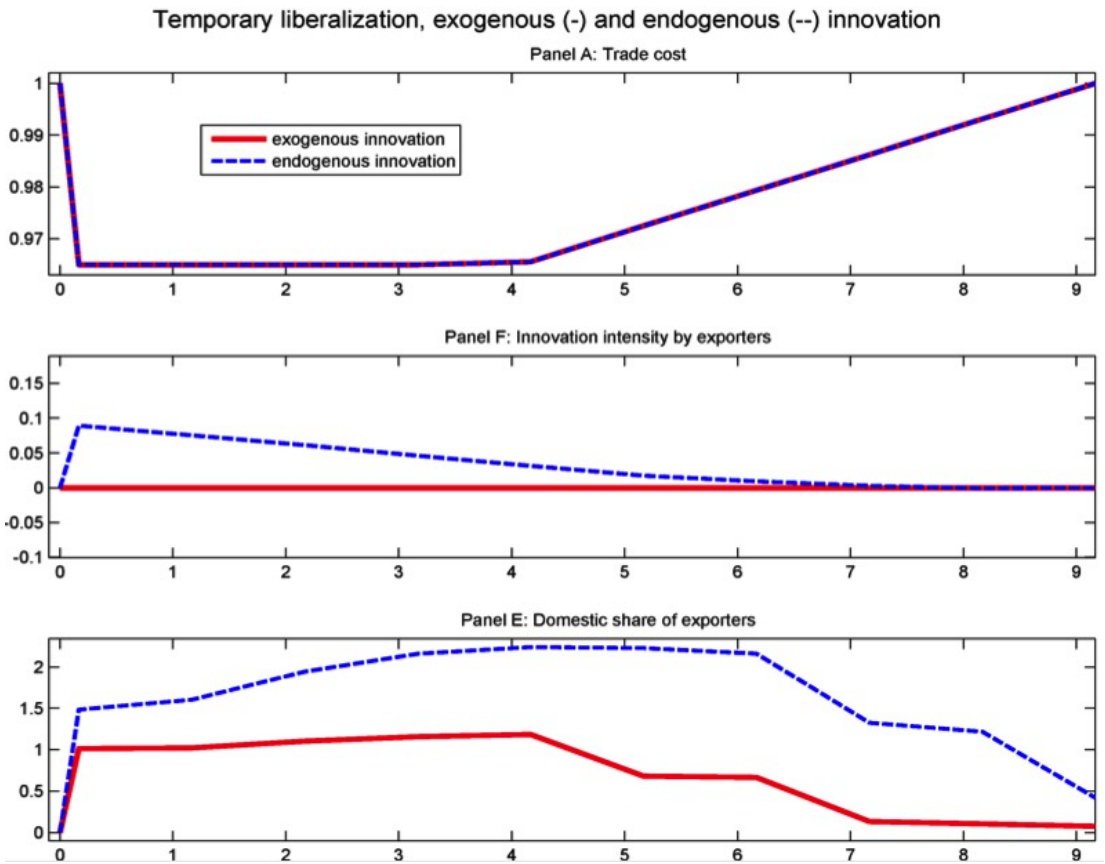
2. Transition dynamics are slow: given incentives, changes in entry and innovation take a long time to unfold

Two key effects:

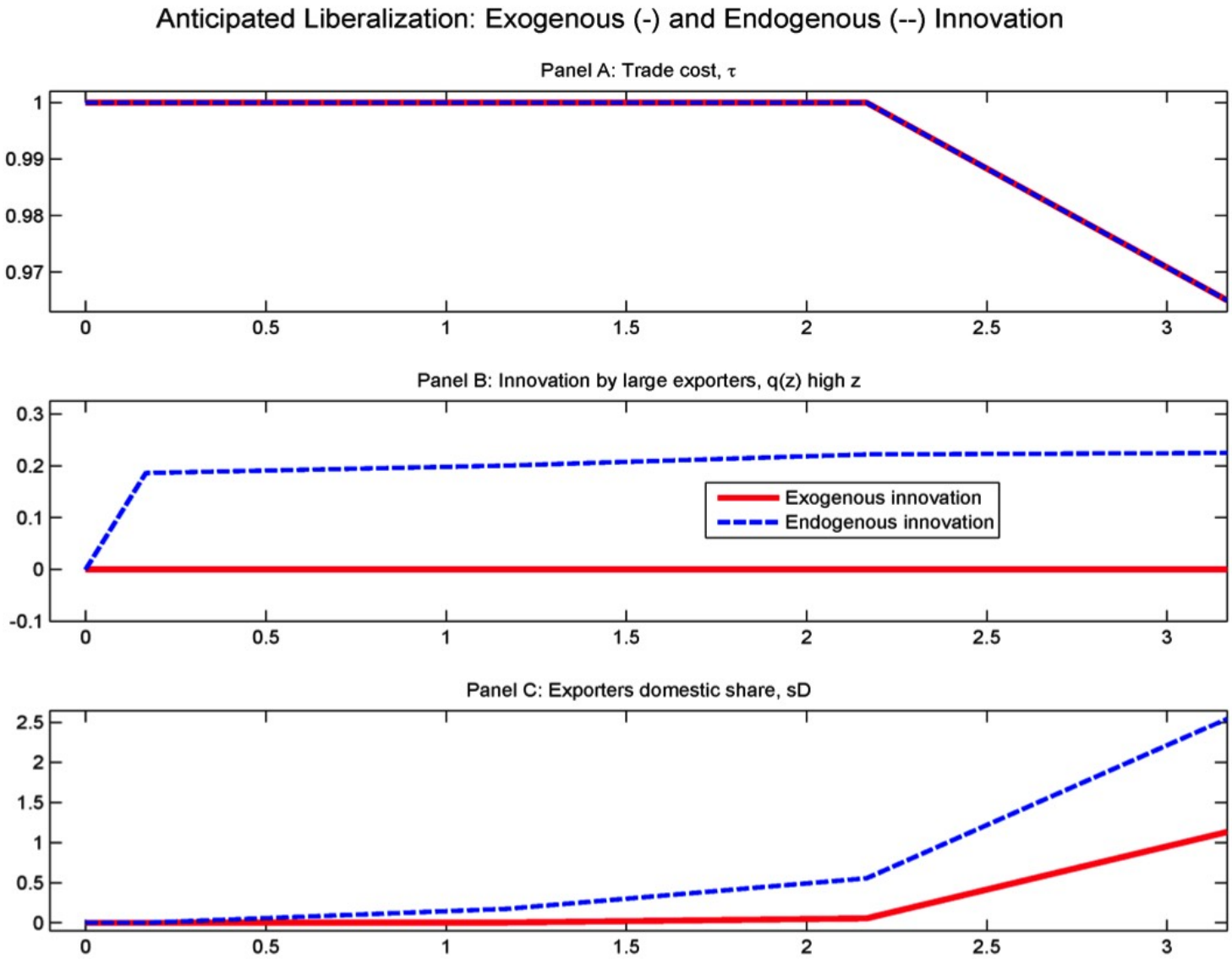
1. Incentives: Entry and innovation responses are forward looking
   - Permanence of trade liberalization affects incentives for entry and innovation
   - Innovation intensity by exporters rises by less when reduction in trade costs is temporary
2. Transition dynamics are slow: given incentives, changes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


Temporary liberalization, exogenous (-) and endogenous (--) innovation
Panel A: Trade cost
exogenous innovation
endogenous innovation
1
0.99
0.98
0.97
0 1 2 3 4 5 6 7 8 9
Panel F: Innovation intensity by exporters
0.15
0.1
0.05
0
-0.05
-0.1
0 1 2 3 4 5 6 7 8 9
Panel E: Domestic share of exporters
2
1.5
1
0.5
0
0 1 2 3 4 5 6 7 8 9

Anticipation Effects: Response of Innovation

- The following figure considers an anticipated, permanent reduction in trade costs (see path of τ 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, τ
1
0.99
0.98
0.97
0
0.5
1
1.5
2
2.5
3
Panel B: Innovation by large exporters, q(z) high z
0.3
0.2
0.1
0
-0.1
Exogenous innovation
Endogenous innovation
Panel C: Exporters domestic share, sD
2.5
2
1.5
1
0.5
0

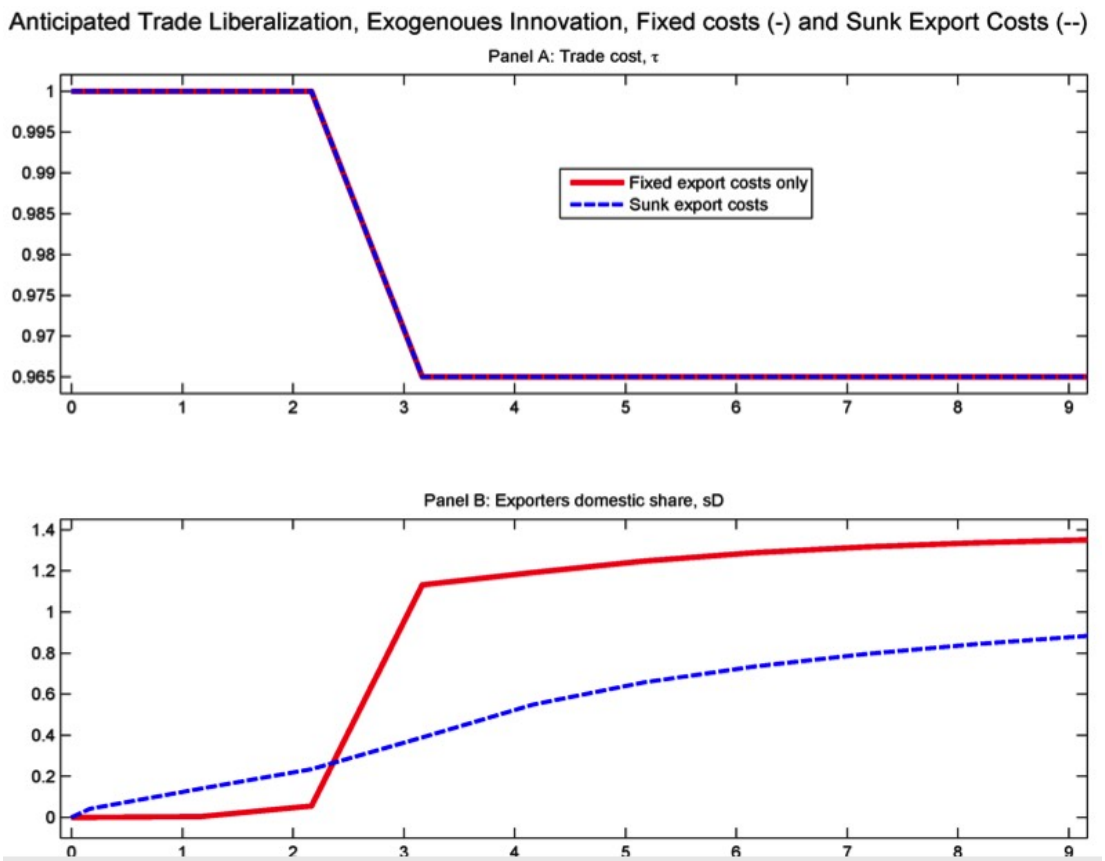
Anticipation Effects: Response of Innovation

Summary

- 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

Anticipation Effects: Sunk Costs and Option Values

- 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, Exogenoues Innovation, Fixed costs (-) and Sunk Export Costs (--)
Panel A: Trade cost, τ
1
0.995
0.99
0.985
0.98
0.975
0.97
0.965
0
1
2
3
4
5
6
7
8
9
Fixed export costs only
Sunk export costs
Panel B: Exporters domestic share, sD
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
7
8
9

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?