Innovation, Firm Dynamics, and International Trade

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Introduction

- How do changes in international trade costs impact aggregate productivity and welfare?

- New Evidence and Theory: International trade impacts heterogeneous firms’ decisions to produce, export, and innovate.
  
  - Theory: e.g. Melitz (2003), Helpman survey (2006)
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- Do considerations of impact of decline in trade costs on these decisions lead to new answers to the macro question?

- Important baseline model: Largely, No.
Model Overview

- Heterogeneous firms produce differentiated CES products, traded subject to fixed and marginal costs of exporting (Melitz 2003).
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- Firms profit opportunities determined by firm-specific factor (productivity).

  - *Process innovation:* Increase stock of specific factor in existing firm.

  - *Product innovation:* Create new firms with new initial stock of factor.
Heterogeneous firms produce differentiated CES products, traded subject to fixed and marginal costs of exporting (Melitz 2003).

Model of innovation builds on Griliches’ (1979).

Firms profit opportunities determined by firm-specific factor (productivity).

- **Process innovation**: Increase stock of specific factor in existing firm.

- **Product innovation**: Create new firms with new initial stock of factor.

Compute *indirect effect* of change in marginal trade costs on aggregate productivity from changes in firms’ exit, export, process, and product innovation.
Analytic results: Special cases


2. Baseline extended to have endogenous exit and productivity dynamics. Do endogenous exit and process innovation matter?

3. Melitz 2003. Fixed export cost implies only most productive firms export. No productivity dynamics implies no process innovation. Does reallocation of production from low to high productivity firms matter?

4. Endogenous process innovation and (exogenous) heterogeneity in exit and export decision. Does reallocation of process innovation from non-exporters to exporters matter?

Cases 3, 4: Steady-state, symmetric countries, interest rate limits 0.
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- *Indirect effect* of change in trade costs on aggregate productivity from changes in firms’ exit, export, process, and product innovation.

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  - Increase in productivity of average firm from changes in exit and exp decisions, reallocation of process innovation from non-exp to exp.
Analytic results: Special cases

- *Indirect effect* of change in trade costs on aggregate productivity from changes in firms’ exit, export, process, and product innovation.

- To a 1st-order approximation, indirect effect $= 0$ in all special cases.
  
  - No additional effect on aggregate productivity over simpler model that abstracts from heterogeneous firms’ decisions.
  
  - Increase in productivity of average firm from changes in exit and exp decisions, reallocation of process innovation from non-exp to exp.

  - Offset by changes in product innovation.
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Firms’ free-entry condition places constraint on overall response of aggregate productivity to change in trade costs.
Quantitative results

- Endogenous selection in production and exporting, elastic process innovation, positive interest rates, large changes in trade costs.
- Parameterization to match features of US export and firm dynamics.
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- Welfare gains from additional indirect effects negligible because transition dynamics are slow.
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Related paper

- Arkolakis, Svetlana, Klenow, and Rodriguez-Clare (2008)
  - Melitz 2003 + Pareto distributed productivities.
  - Abstract from process innovation.
  - Welfare gains of reduction in trade costs same with and without heterogeneous exporting decisions, given initial trade share and trade elasticity.
Production of final goods

- Preferences of representative hh: $\sum_{t=0}^{\infty} \beta^t \log(C_t)$

- Production function of final good:

$$Y_t = \left[ \int a(t)(z)^{1-1/\rho} \, dM_t(z) + \int x_t^*(z) b_t(z)^{1-1/\rho} \, dM_t^*(z) \right]^{\rho/(\rho-1)}$$

- $M(z)$: measure of operating intermediate goods firms with productivity index $z$.

- Produced by competitive firms.

- Standard demands and final good price $P_t$. 

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Production of intermediate goods

- Firms indexed by $z$.

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

- Fixed operating cost: $n_f$ units of research good.
Production of intermediate goods

- Firms indexed by $z$.

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

- Fixed operating cost: $n_f$ units of research good.

- Per-period fixed export cost: $n_x$ units of research good.

- Iceberg cost $D > 1$ in exported goods.
Firms are monopolistically competitive.

Current static profits:

\[ \Pi_t(z) = \max_{y, l, p_a, p_a^*, a, a^*, x \in \{0, 1\}} p_a a + x p_a^* a^* - W_t l - x n_x \]

\[ a + x D a^* = \exp(z)^{1/(\rho-1)} l \]

\[ a = \left( \frac{p_a}{P_t} \right)^{-\rho} Y_t \quad \text{and} \quad a^* = \left( \frac{p_a^*}{P_t^*} \right)^{-\rho} Y_t^*. \]
Firms are monopolistically competitive.

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$$a = \left(\frac{p_a}{P_t}\right)^{-\rho} Y_t$$ and $$a^* = \left(\frac{p_a^*}{P_t^*}\right)^{-\rho} Y_t^*$$.

Symmetric countries:

$$\Pi_t(z) = \Pi_{dt} \exp(z) + \max \{ \Pi_{dt} D^{1-\rho} \exp(z) - n_x, 0 \}$$

$$\Pi_d = \frac{(W / P)^{1-\rho} P Y}{\rho^\rho (\rho - 1)^{1-\rho}}$$
Process innovation

- Firm with current productivity $\exp(z)^{1/(\rho-1)}$, productivity at $t + 1$:
  - $\exp(z + \Delta z)^{1/(\rho-1)}$ with probability $q$
  - $\exp(z - \Delta z)^{1/(\rho-1)}$ with probability $1 - q$.

- Firm invests $\exp(z) c(q)$ units of research good, $c_q > 0$, $c_{qq} > 0$.  

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Process innovation

- Firm’s dynamic problem:

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

\[ V^o_t(z) = \max_{q \in [0, 1]} \Pi_t(z) - \exp(z) c(q) - n_f + (1 - \delta) \frac{1}{R_t} [qV_{t+1}(z + \Delta_z) + (1 - q)V_{t+1}(z - \Delta_z)]. \]

- Implies exit cutoff \( \bar{z}_t \) and \( q_t(z) \).
Product innovation

- Free-entry:

\[ n_e = \frac{1}{R_t} \int V_{t+1}(z) dG \]

- \( G(z) \): distribution of initial productivity draws.

- \( G(z) \) constant over time.
Feasibility constraints

- Research good:

\[
M_{et} n_e + \int [n_f + x_t(s) n_x + \exp(z)c(q_t(s))] \, dM_t = L_{rt}^\lambda Y_{rt}^{1-\lambda}
\]

- Assume \( \rho + \lambda > 2 \).
Feasibility constraints

- **Research good:**
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  \]
  - Assume \( \rho + \lambda > 2 \).

- **Labor:**
  \[
  \int l_t(z) dM_t(z) + L_{rt} = L
  \]

- **Final good:**
  \[
  C_t + Y_{rt} = Y_t
  \]

- Evolution of \( M_t(z) \) over time is implied by \( q_t(z), \delta, \) and \( \tilde{z}_t \).
Aggregate productivity

- Aggregate output:

\[ Y = Z (L - L_r) \]
Aggregate productivity

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- Aggregate productivity symmetric steady-state:

\[ Z = \left[ M_e (Z_d + (1 + D^{1-\rho}) Z_x) \right]^{1/(\rho-1)} \]

\[ Z_d = \int (1 - x(z)) \exp(z) \text{d}\tilde{M}(z), \quad Z_x = \int x(z) \exp(z) \text{d}\tilde{M}(z) \]
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- Change in aggregate productivity:

\[ \Delta \log Z = -s_x \Delta \log D + \underbrace{\frac{1}{\rho-1} \left[ s_x \frac{1 + D^{1-\rho}}{D^{1-\rho}} \Delta \log Z_x + \left(1 - s_x \frac{1 + D^{1-\rho}}{D^{1-\rho}}\right) \Delta \log Z_d + \Delta \log M_e \right]}_{\text{Indirect effect}} \]

Direct effect

Indirect effect

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  \]

- Change in aggregate productivity:
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  \]

- How big is the indirect effect?
First, find constant on variable profits

Given $\Pi_d$, exit, export, and process innovation decisions:

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

$$V^o(z) = \max_{q \in [0,1]} \Pi_d \exp(z) + \max \left\{ \Pi_d D^{1-\rho} \exp(z) - n_x, 0 \right\} - \exp(z) c(q) - n_f$$

$$+ (1 - \delta) \beta [qV(z + \Delta z) + (1 - q)V(z - \Delta z)].$$
First, find constant on variable profits

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- Solve $\Pi_d$ from free-entry condition:

$$n_e = \beta \int V(z) dG.$$
Then, calculate indirect effect on aggregate productivity

- Constant on variable profits: \( \Pi_d = \kappa \left( \frac{W}{P} \right)^{1-\rho-\lambda} Y \).
Then, calculate indirect effect on aggregate productivity

- Constant on variable profits: \( \Pi_d = \kappa \left( \frac{W}{P} \right)^{1-\rho-\lambda} Y \).

- Using: \( \frac{W}{P} = \frac{\rho-1}{\rho} Z \) and \( Y = Z (L - L_r) \).
Then, calculate indirect effect on aggregate productivity

- Constant on variable profits: \( \Pi_d = \kappa (W/P)^{1-\rho-\lambda} Y \).

- Using: \( \frac{W}{P} = \frac{\rho-1}{\rho} Z \) and \( Y = Z (L - L_r) \).

- \( \Pi_d = \kappa' Z^{2-\rho-\lambda} (L - L_r) \).

\[ \Delta \log \Pi_d = (2 - \rho - \lambda) \ast (\text{Direct Eff} + \text{Indirect Eff}) + \Delta \log (L - L_r) \]
Then, calculate indirect effect on aggregate productivity

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\[
\Delta \log \Pi_d = (2 - \rho - \lambda) \times (\text{Direct Eff} + \text{Indirect Eff}) + \Delta \log (L - L_r)
\]

- If all firms export or \( \beta \rightarrow 1 \), \( \Delta \log (L - L_r) = 0 \)
Then, calculate indirect effect on aggregate productivity

- **Constant on variable profits:** \( \Pi_d = \kappa \left( \frac{W}{P} \right)^{1-\rho-\lambda} Y. \)

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- If all firms export or \( \beta \rightarrow 1, \Delta \log (L - L_r) = 0 \)

- **Four special cases:** \( \Delta \log \Pi_d = (\rho - 1) s_x \Delta \log D. \)
Then, calculate indirect effect on aggregate productivity

- Constant on variable profits: \( \Pi_d = \kappa (W/P)^{1-\rho-\lambda} Y. \)

- Using: \( \frac{W}{P} = \frac{\rho-1}{\rho} Z \) and \( Y = Z (L - L_r). \)

- \( \Pi_d = \kappa' Z^{2-\rho-\lambda} (L - L_r). \)

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\Delta \log \Pi_d = (2 - \rho - \lambda) \ast (\text{Direct Eff} + \text{Indirect Eff}) + \Delta \log (L - L_r)
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- Four special cases: \( \Delta \log \Pi_d = (\rho - 1) s_x \Delta \log D. \)

- Implies indirect effect and \( \Delta \log Z \) equal in all cases.
Aggregate allocation of labor

- CES aggregator: Payments to production employment fixed ratio of variable profits.
  \[ W(L - L_r) = (\rho - 1) \Pi_d Z \]

- CD production of research good:
  \[ WL_r = \lambda Y M_e \]
  where
  \[ Y = n_e + \int [n_f + x(z) n_x + \exp(z) c(q(z))] \, d\tilde{M}(z). \]

- Combine:
  \[ \frac{L - L_r}{L_r} = \frac{\rho - 1}{\lambda} \frac{\Pi_d Z}{Y M_e} \]

- Zero interest rate, no economic profits, \( \frac{\Pi_d Z}{Y M_e} = 1 \).

- Positive interest rate, economic profits non-constant, \( \frac{\Pi_d Z}{Y M_e} > 1 \).
Benchmark: Only product innovation (Krugman 1979)

- All firms produce, export, no process innovation.
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- Values functions:

\[ V(z) = \frac{\Pi_D (1 + D^{1-\rho})}{1 - \beta (1 - \delta)} \exp(z) \]
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- Values functions:
  \[ V(z) = \frac{\Pi_d (1 + D^{1-\rho})}{1 - \beta (1 - \delta)} \exp(z) \]

- Free-entry condition requires \( \Pi_d (1 + D^{1-\rho}) \) constant.

- \( \Delta \log \Pi_d = (\rho - 1) s_x \Delta \log D \).
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- \( \Delta \log \Pi_d = (\rho - 1) s_x \Delta \log D \).

- Indirect effect on aggregate productivity:
  \[
  \frac{\text{Indirect effects}}{\text{Direct effect}} = \frac{1 - \lambda}{\rho + \lambda - 2}
  \]
Case I: Productivity dynamics, exit, all firms export

Values functions:

\[
V^o(z) = \max_{q \in [0,1]} \Pi_d (1 + D^{1-\rho}) \exp(z) - \exp(z) c(q) - n_f + (1 - \delta) \beta \left[ q V(z + \Delta z) + (1 - q) V(z - \Delta z) \right]
\]
Case I: Productivity dynamics, exit, all firms export

- Values functions:

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V^o(z) = \max_{\Pi_d} \left( (1 + D^{1-\rho}) \exp(z) - \exp(z) c(q) - n_f + (1 - \delta) \beta \left[ qV(z + \Delta_z) + (1 - q)V(z - \Delta_z) \right] \right)
\]

- Free-entry condition requires \( \Pi_d (1 + D^{1-\rho}) \) fixed, \( \Delta \log \Pi_d \) as before

- Exit, process innovation unchanged.
Case I: Productivity dynamics, exit, all firms export

Values functions:

\[ V^o(z) = \max_{q\in[0,1]} \Pi_d (1 + D^{1-\rho}) \exp(z) - \exp(z) c(q) - n_f + (1 - \delta) \beta [qV(z + \Delta z) + (1 - q)V(z - \Delta z)] \]

Free-entry condition requires \( \Pi_d (1 + D^{1-\rho}) \) fixed, \( \Delta \log \Pi_d \) as before

Exit, process innovation unchanged.

Indirect effect (only from product innovation):

\[
\frac{\text{Indirect effect}}{\text{Direct effect}} = \frac{1 - \lambda}{\rho + \lambda - 2}
\]
Case II: Subset of firms export, no productivity dynamics

- $n_x > 0$, $\Delta z = 0$, no process innovation
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- \( n_x > 0, \Delta_z = 0 \), no process innovation

- \( V(z) = \frac{1}{1 - \beta (1 - \delta)} \max \left\{ 0, \Pi_d e^z - n_f + \max \left\{ 0, \Pi_d e^z D^{1 - \rho} - n_x \right\} \right\} \).
Case II: Subset of firms export, no productivity dynamics

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- Differentiate free-entry to obtain $\Delta \log \Pi_d$.

- No first-order effects on $V(z)$ from changes in $\bar{z}$ and $\bar{z}_x$ (envelope)

- Gives $\Delta \log \Pi_d = (\rho - 1) s_x \Delta \log D$
Case II: Subset of firms export, no productivity dynamics

- \( n_x > 0, \Delta z = 0, \) no process innovation

\[
V(z) = \frac{1}{1-\beta(1-\delta)} \max \left\{ 0, \Pi_d e^z - n_f + \max \left\{ 0, \Pi_d e^z D^{1-\rho} - n_x \right\} \right\}.
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- Differentiate free-entry to obtain \( \Delta \log \Pi_d. \)

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- Gives \( \Delta \log \Pi_d = (\rho - 1) s_x \Delta \log D \)

- If \( \beta \to 1 \) or \( G(z) \) Pareto, \( \Delta L_r = 0, \) and

\[
\frac{\text{Indirect effect}}{\text{Direct effect}} = \frac{1 - \lambda}{\rho + \lambda - 2}
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Case II: Subset of firms export, no productivity dynamics

- $n_x > 0$, $\Delta z = 0$, no process innovation

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- No first-order effects on $V(z)$ from changes in $\bar{z}$ and $\bar{z}_x$ (envelope)

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- If $\beta \to 1$ or $G(z)$ Pareto, $\Delta L_r = 0$, and

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  \frac{\text{Indirect effect}}{\text{Direct effect}} = \frac{1 - \lambda}{\rho + \lambda - 2}
  \]

- Product innovation offsets changes in exit and export decisions.
Case III: Productivity dynamics, exogenous selection

- $\Delta z > 0$, allow for process innovation

- Export status follows Markov process, $n_x \in \{0, \infty\}$

- Only exogenous exit: $n_f = 0$.

- $V(z, n_x) = V_i \exp(z)$, and $q(z, n_x) = q_i$. 
Case III: Productivity dynamics, exogenous selection

- $\Delta z > 0$, allow for process innovation

- Export status follows Markov process, $n_x \in \{0, \infty\}$

- Only exogenous exit: $n_f = 0$.

- $V(z, n_x) = V_i \exp(z)$, and $q(z, n_x) = q_i$.

- In response to a decline in $D$, $q_{\text{exp}}$ increases relative to $q_{\text{non-exp}}$.

- Magnitude depends on $c''(q) / c'(q)$. 
Case III: Productivity dynamics, exogenous selection

- Differentiate free-entry condition.

- Process innovation chosen optimally, no first-order effects from $\frac{\partial q}{\partial D}$ on $V(z)$
Case III: Productivity dynamics, exogenous selection

- Differentiate free-entry condition.

- Process innovation chosen optimally, no first-order effects from \( \frac{\partial q}{\partial D} \) on \( V(z) \)

- With \( \beta \to 1 \), \( \Delta \log \Pi_d \) as before, \( \Delta \log L_r = 0 \), and

\[
\frac{\text{Indirect effect}}{\text{Direct effect}} = \frac{1 - \lambda}{\rho + \lambda - 2}
\]
Case III: Productivity dynamics, exogenous selection

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- With $\beta \rightarrow 1$, $\Delta \log \Pi_d$ as before, $\Delta \log L_r = 0$, and

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\frac{\text{Indirect effect}}{\text{Direct effect}} = \frac{1 - \lambda}{\rho + \lambda - 2}
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- Decline in product innovation offsets reallocation of process innov.
Case III: Productivity dynamics, exogenous selection

- Differentiate free-entry condition.

- Process innovation chosen optimally, no first-order effects from $\frac{\partial q}{\partial D}$ on $V(z)$

- With $\beta \to 1$, $\Delta \log \Pi_d$ as before, $\Delta \log L_r = 0$, and

$$\frac{\text{Indirect effect}}{\text{Direct effect}} = \frac{1 - \lambda}{\rho + \lambda - 2}$$

- Decline in product innovation offsets reallocation of process innov.

- $c''/c'$ has no impact on $\Delta \log Z$. 
Case III: Positive real interest rates

- Change in profits:

\[ \Delta \log \Pi_d = (\rho - 1) \times \tilde{s}_x \times \Delta \log D \]

\( \tilde{s}_x \) = share of exports in discounted present value of revenues for entering firm.

- Reallocation of labor from research to production, change in economic profits \( \Pi_d Z / \Upsilon \).
Case III: Positive real interest rates

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\[ \Delta \log \Pi_d = (\rho - 1) * \tilde{s}_x * \Delta \log D \]

\[ \tilde{s}_x \text{ = share of exports in discounted present value of revenues for entering firm.} \]

- Reallocation of labor from research to production, change in economic profits \( \Pi_d Z / \Upsilon \).

- Exogenous selection, inelastic process innovation, \( \lambda = 1 \):

\[ \frac{\text{Indirect effect}}{\text{Direct effect}} = \left( \frac{\tilde{s}_x}{s_x} - 1 \right) \left( 1 - \frac{L_r}{L} \right) \]

- Indirect effect < 0 (decline in product innovation) if \( \tilde{s}_x < s_x \).
Case III: Transition dynamics

- Transition dynamics of aggregate productivity indices:

\[
\begin{pmatrix}
Z_{xt} - \bar{Z}_x \\
Z_{dt} - \bar{Z}_d
\end{pmatrix}
= (1 - \delta)^t A^t
\begin{pmatrix}
Z_{x0} - \bar{Z}_x \\
Z_{d0} - \bar{Z}_d
\end{pmatrix}
\]

- If \((1 - \delta)^t A^t\) dies out slowly, then transition dynamics are slow.
Case III: Transition dynamics

- Transition dynamics of aggregate productivity indices:

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Z_{xt} - \bar{Z}_x \\
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\begin{pmatrix}
Z_{x0} - \bar{Z}_x \\
Z_{d0} - \bar{Z}_d
\end{pmatrix}
\]

- If \((1 - \delta)^t A^t\) dies out slowly, then transition dynamics are slow.

- Productivity:

  - Entering firms: \([(1 + D^{1-\rho}) 1] [g_l \ g_h]'\).
  - Average firm: \([(1 + D^{1-\rho}) 1] \sum_{t=0}^{\infty} (1 - \delta)^t A^t [g_l \ g_h]'\).

- If \((1 - \delta)^t A^t\) dies out slowly, then productivity of average firm is substantially larger than the average productivity of an entering firm.

- When process innovation plays big role in determining firms’ productivities, then transition dynamics slow.
Quantitative Analysis

- Simultaneously include:
  - endogenous selection in firms’ exit and export decisions.
  - endogenous process innovation.

- Vary real interest rate and elasticity of process innovation to changes in incentive to innovate.

- Consider larger changes in variable trade costs.
Parameterization

- \( c''(q) / c'(q) = b. \)

- High \( b \): inelastic process innovation.

- Low \( b \): elastic process innovation.
Parameterization

- New firms \( z = z_0 \)

- Calibrate \( (h, \Delta z, D^{1-\rho}, n_x, \text{and } \delta) \) to US data on:
  - Firm employment-based size distribution.
  - Variance of growth of large firms.
  - Death of large firms.
  - Exports / Gross Output.
  - Employment in exporting firms

- Adjust \( h \) to keep \( q \) of large firms constant as we lower \( b \).

- Other parameters, do not affect calibration targets: \( \rho = 5, n_f, n_e \).
Reduction (small) in marginal trade costs, \( r=0 \)

<table>
<thead>
<tr>
<th></th>
<th>Research good produced with labor only</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \lambda = 1 )</td>
<td></td>
</tr>
<tr>
<td>Curvature of process innovation cost function, ( b )</td>
<td>3000  30  10</td>
</tr>
<tr>
<td><strong>Elasticity of aggregate variables across steady-states</strong></td>
<td></td>
</tr>
<tr>
<td>negative of ( \log ) change in variable / ( \log ) change in D</td>
<td></td>
</tr>
<tr>
<td>Aggregate productivity, ( Z )</td>
<td>0.075  0.075  0.076</td>
</tr>
<tr>
<td>Direct effect</td>
<td>0.075  0.075  0.076</td>
</tr>
<tr>
<td>Productivity of the average firm</td>
<td>0.00   1.17   3.85</td>
</tr>
<tr>
<td>Product Innovation</td>
<td>0.00   -1.17 -3.87</td>
</tr>
<tr>
<td>Ratio indirect / direct effect, theoretical and numerical</td>
<td>0.00  0.00   0.00</td>
</tr>
</tbody>
</table>
Reduction (small) in marginal trade costs, $r=0$

<table>
<thead>
<tr>
<th></th>
<th>Research good produced with labor + goods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\lambda=0.5$</td>
</tr>
<tr>
<td>Curvature of process innovation cost function, $b$</td>
<td>3000</td>
</tr>
</tbody>
</table>

**Elasticity of aggregate variables across steady-states**

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate productivity, $Z$</td>
<td>0.086</td>
<td>0.086</td>
<td>0.087</td>
</tr>
<tr>
<td>Direct effect</td>
<td>0.075</td>
<td>0.075</td>
<td>0.076</td>
</tr>
<tr>
<td>Productivity of the average firm</td>
<td>0.00</td>
<td>1.17</td>
<td>3.85</td>
</tr>
<tr>
<td>Product Innovation</td>
<td>0.01</td>
<td>-1.16</td>
<td>-3.86</td>
</tr>
<tr>
<td>Ratio indirect / direct effect, theoretical and numerical</td>
<td>0.14</td>
<td>0.14</td>
<td>0.14</td>
</tr>
</tbody>
</table>
Reduction in marginal trade costs, $r=0.05$, elastic $q$

<table>
<thead>
<tr>
<th></th>
<th>$\lambda=1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curvature of process innovation cost function, $b$</td>
<td>3,000 30 10</td>
</tr>
<tr>
<td>Elasticity of aggregate variables across steady-states</td>
<td></td>
</tr>
<tr>
<td>Aggregate Production Labor, $L-L_r$</td>
<td>0.02 0.11 0.29</td>
</tr>
<tr>
<td>Aggregate productivity, $Z$</td>
<td>0.009 0.037 0.095</td>
</tr>
<tr>
<td>Direct effect</td>
<td>0.076 0.076 0.075</td>
</tr>
<tr>
<td>Productivity of the average firm</td>
<td>0.00 0.63 2.66</td>
</tr>
<tr>
<td>Product Innovation</td>
<td>-0.07 -0.67 -2.65</td>
</tr>
<tr>
<td>Ratio indirect / direct effect, numerical</td>
<td>-0.88 -0.52 0.26</td>
</tr>
<tr>
<td>Output</td>
<td>0.03 0.15 0.39</td>
</tr>
</tbody>
</table>
Reduction in marginal trade costs, $r=0.05$, welfare

<table>
<thead>
<tr>
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<th>$\lambda=1$</th>
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<tbody>
<tr>
<td>Curvature of process innovation cost function, $b$</td>
<td>3,000 30 10</td>
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</table>

**Elasticity of aggregate variables across steady-states**

<table>
<thead>
<tr>
<th>Aggregate productivity, $Z$</th>
<th>0.009 0.037 0.095</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct effect</td>
<td>0.076 0.076 0.075</td>
</tr>
<tr>
<td>Productivity of the average firm</td>
<td>0.000 0.626 2.660</td>
</tr>
<tr>
<td>Product Innovation</td>
<td>-0.067 -0.666 -2.651</td>
</tr>
<tr>
<td>Output, $Y$</td>
<td>0.030 0.148 0.387</td>
</tr>
<tr>
<td>Welfare</td>
<td>0.076 0.076 0.076</td>
</tr>
<tr>
<td>Welfare in benchmark (all firms export, exog. exit)</td>
<td>0.075 0.075 0.075</td>
</tr>
</tbody>
</table>
Transition dynamics

In paper we show: larger steady-state change, slower transition.
Transition dynamics

Larger steady-state change, slower transition.
Larger reduction in marginal trade costs

<table>
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<th>( \lambda = 1 )</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curvature of process innovation cost function, b</td>
<td>3,000</td>
<td>30</td>
</tr>
<tr>
<td>Export share, initial steady state</td>
<td>0.076</td>
<td>0.076</td>
</tr>
<tr>
<td>Export share, new steady state</td>
<td>0.093</td>
<td>0.110</td>
</tr>
<tr>
<td>Elasticity of aggregate variables across steady-states</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate productivity, Z</td>
<td>0.007</td>
<td>0.042</td>
</tr>
<tr>
<td>Direct effect + productivity of the average firm (*)</td>
<td>0.11</td>
<td>0.92</td>
</tr>
<tr>
<td>Product Innovation</td>
<td>-0.10</td>
<td>-0.88</td>
</tr>
<tr>
<td>Welfare</td>
<td>0.084</td>
<td>0.086</td>
</tr>
<tr>
<td>Welfare in benchmark (all firms export, exog. exit)</td>
<td>0.081</td>
<td>0.081</td>
</tr>
</tbody>
</table>

Atkeson and Burstein
Innovation, dynamics, international trade
November 10, 2009
Conclusions

- Build model of the endogenous change in aggregate productivity that arises in GE as firms’ exit, export, process- and product innovation decisions respond to change in trade costs.
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- Trade cost change can have substantial effect on individual firms’ decisions, but largely not reflected in aggregate productivity and welfare.
Conclusions

- Build model of the endogenous change in aggregate productivity that arises in GE as firms’ exit, export, process- and product innovation decisions respond to change in trade costs.

- Trade cost change can have substantial effect on individual firms’ decisions, but largely not reflected in aggregate productivity and welfare.

- Micro evidence on elasticity of individual firms’ exit, export and process innovation to changes in international trade costs not informative about the macroeconomic implications of these responses for aggregate productivity and welfare.
Future work

- Non-constant elasticity of demand leading to variable markups and strategic interaction in firms affecting process innovation decisions.

- Multi-product firms.

- Spillovers leading to endogenous growth.

- Innovation policies designed to stimulate innovation at the firm level.