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.

  - Evidence: e.g. Bernard, Jensen, Redding, Schott (2007), Bustos (07), De Locker (07), Lileeva, Trefler (2007), Aw, Roberts, Xu (2009).
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  - Theory: e.g. Melitz (2003), Helpman survey (2006)
- 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

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- *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

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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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- Firms' free-entry condition places constraint on overall response of aggregate productivity to change in trade costs.

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  - Welfare gains from additional indirect effects negligible because transition dynamics are slow.

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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- 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.

Profits

- Firms are monopolistically competitive.

- Current static profits:

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

$$a + xDa^* = \exp(z)^{1/(\rho-1)} l$$

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

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- Symmetric countries:

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

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

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, $c_q > 0$, $c_{qq} > 0$.

Process innovation

- Firm's dynamic problem:

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

$$V_t^o(z) = \max_{q\in[0,1]} \Pi_t(z) - \exp(z)\, c(q) - n_f +$$

$$(1-\delta)\frac{1}{R_t}\left[qV_{t+1}(z+\Delta_z) + (1-q)V_{t+1}(z-\Delta_z)\right].$$

- 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:

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

  - Assume $\rho + \lambda > 2$.

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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 $q_t(z)$, δ, and $\bar{z}_t$.

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

$$Z_d = \int\left(1 - x\left(z\right)\right)\exp(z)\mathrm{d}\tilde{M}\left(z\right)\ ,\ Z_x = \int x\left(z\right)\exp(z)\mathrm{d}\tilde{M}\left(z\right)$$

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- Change in aggregate productivity:

$$\Delta \log Z = \underbrace{-s_x \Delta \log D}_{\textbf{Direct effect}} +$$

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

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- How big is the indirect effect?

First, find constant on variable profits

- Given Π_d, exit, export, and process innovation decisions:

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

$$V^o(z) =$$

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

$$+(1-\delta)\beta\left[qV(z+\Delta_z) + (1-q)V(z-\Delta_z)\right].$$

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- Solve Π_d from free-entry condition:

$$n_e = \beta \int V(z) dG.$$

Then, calculate indirect effect on aggregate productivity

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- Using: $\frac{W}{P} = \frac{\rho-1}{\rho} Z$ and $Y = Z\left(L - L_r\right)$.
- $\Pi_d = \kappa' Z^{2-\rho-\lambda}\left(L - L_r\right)$.

  $$\Delta \log \Pi_d = \left(2-\rho-\lambda\right) * \left(\text{Direct Eff} + \text{Indirect Eff}\right) + \Delta \log\left(L - L_r\right)$$

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- Four special cases: $\Delta \log \Pi_d = (\rho - 1)\, s_x \Delta \log D$.

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- 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.

$$W\left(L-L_r\right)=\left(\rho-1\right)\Pi_d Z$$

- CD production of research good:

$$WL_r=\lambda \Upsilon M_e$$

where

$$\Upsilon=n_e+\int\left[n_f+x\left(z\right)n_x+\exp(z)c(q(z))\right]\mathrm{d}\tilde{M}(z).$$

- Combine:

$$\frac{L-L_r}{L_r}=\frac{\rho-1}{\lambda}\frac{\Pi_d Z}{\Upsilon M_e}$$

- Zero interest rate, no economic profits, $\frac{\Pi_d Z}{\Upsilon M_e}=1$.

- Positive interest rate, economic profits non-constant, $\frac{\Pi_d Z}{\Upsilon M_e}>1$.

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- 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:

$$
\begin{aligned}
V^{o}(z) \quad = \quad & \max_{q \in [0,1]} \Pi_d \left(1 + D^{1-\rho}\right) \exp\left(z\right) - \exp\left(z\right) c\left(q\right) - n_f + \\
& (1-\delta)\beta\left[qV(z + \Delta_z) + (1-q)V(z - \Delta_z)\right]
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- If $\beta \rightarrow 1$ or $G(z)$ Pareto, $\Delta L_r = 0$, and

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- 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 $q(z, n_x) = q_i$.

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- 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_{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.

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

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- Decline in product innovation offsets reallocation of process innov.

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- With $\beta \longrightarrow 1$, $\Delta \log \Pi_d$ 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:

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

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

- Reallocation of labor from research to production, change in economic profits $\Pi_d Z/Y$.

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- 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:

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

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

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- Productivity:
  - Entering firms: $\left[\left(1 + D^{1-\rho}\right) \;\; 1\right] [g_l \;\; g_h]'$.
  - Average firm: $\left[\left(1 + D^{1-\rho}\right) \;\; 1\right] \sum_{t=0}^{\infty} (1-\delta)^t A^t [g_l \;\; g_h]'$.
  - 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, Δ_z, $D^{1-\rho}$, n_x,and δ) 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

	Research good produced with labor only		
		λ=1	
Curvature of process innovation cost function, b	3000	30	10
Elasticity of aggregate variables across steady-states			
negative of log change in variable / log change in D			
Aggregate productivity, Z	0.075	0.075	0.076
Direct effect	0.075	0.075	0.076
Productivity of the average firm	0.00	1.17	3.85
Product Innovation	0.00	-1.17	-3.87
Ratio indirect / direct effect, theroetical and numerical	0.00	0.00	0.00

Reduction (small) in marginal trade costs, r=0

	Research good produced with labor + gooc		
		λ=0.5	
Curvature of process innovation cost function, b	3000	30	10
Elasticity of aggregate variables across steady-states			
Aggregate productivity, Z	0.086	0.086	0.087
Direct effect	0.075	0.075	0.076
Productivity of the average firm	0.00	1.17	3.85
Product Innovation	0.01	-1.16	-3.86
Ratio indirect / direct effect, theoretical and numerical	0.14	0.14	0.14

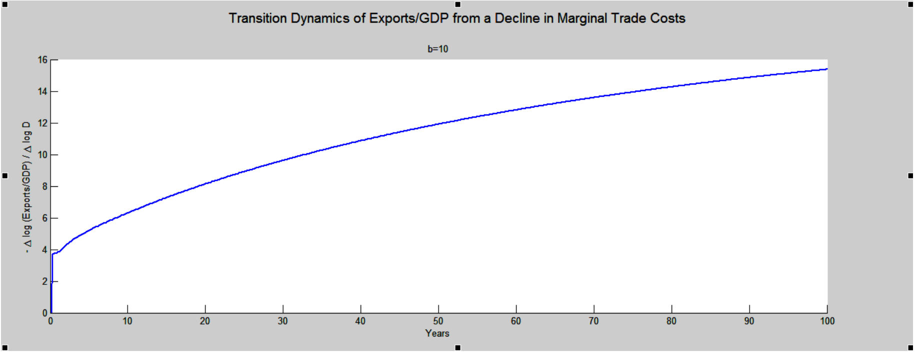
Reduction in marginal trade costs, r=0.05, elastic q

			λ=1	
Curvature of process innovation cost function, b		3,000	30	10
Elasticity of aggregate variables across steady-states				
Aggregate Production Labor, $L-L_r$		0.02	0.11	0.29
Aggregate productivity, Z		0.009	0.037	0.095
	Direct effect	0.076	0.076	0.075
	Productivity of the average firm	0.00	0.63	2.66
	Product Innovation	-0.07	-0.67	-2.65
Ratio indirect / direct effect, numerical		-0.88	-0.52	0.26
Output		0.03	0.15	0.39

Reduction in marginal trade costs, r=0.05, welfare

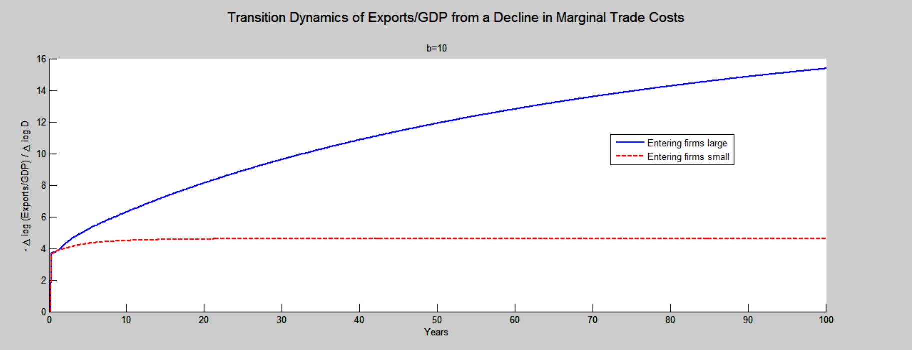
		λ=1	
Curvature of process innovation cost function, b	3,000	30	10
Elasticity of aggregate variables across steady-states			
Aggregate productivity, Z	0.009	0.037	0.095
Direct effect	0.076	0.076	0.075
Productivity of the average firm	0.000	0.626	2.660
Product Innovation	-0.067	-0.666	-2.651
Output, Y	0.030	0.148	0.387
Welfare	0.076	0.076	0.076
Welfare in benchmark (all firms export, exog. exit)	0.075	0.075	0.075

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

	Research good produced with labor only		
		λ=1	
Curvature of process innovation cost function, b	3,000	30	10
Export share, initial steady state	0.076	0.076	0.075
Export share, new steady state	0.093	0.110	0.206
Elasticity of aggregate variables across steady-states			
Aggregate productivity, Z	0.007	0.042	0.195
Direct effect + productivity of the average firm (*)	0.11	0.92	14.49
Product Innovation	-0.10	-0.88	-14.29
Welfare	0.084	0.086	0.092
Welfare in benchmark (all firms export, exog. exit)	0.081	0.081	0.081

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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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.