Equilibrium Technology Diffusion, Trade, and Growth

Jesse Perla
University of British Columbia

Chris Tonetti
Stanford GSB, NBER

Michael E. Waugh
New York University, NBER

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Big Picture

Big Questions:

- Why does opening to trade lead to productivity gains at the firm level?
- What are the consequences of these within-firm productivity gains for aggregate economic growth and welfare?

This Paper:

- A new theory of how openness affects a firms' decision to improve its productivity through technology adoption.
- Very sharp characterization of the mechanisms behind...
  - The choices of a firm,
  - The aggregate growth effects,
  - The gains from trade.

Our Model...

Open economy, continuous time, GE extension of Perla and Tonetti (2014).

- Growth from technology adoption.
- Related to "idea flow" work by Lucas (2010), Lucas and Moll (2014), Alvarez, Buera, Lucas (2014), Sampson (2016), Buera and Oberfield (2016)

Trade as in Melitz (2003)...

- Heterogenous firms, monopolistic competition with fixed cost of exporting
- Free entry

Not a model of innovation or cross-country technology diffusion.

Main Results

1. Characterize growth as a function of statistics of the profit distribution—the ratio of profits between the average and marginal firm.

- Encodes the trade-off that firms face in technology adoption:
  The expected benefit versus the opportunity cost of adoption.

- Import competition erodes profits of low-productivity firms $\Rightarrow$
  lowers opportunity cost of adoption $\Rightarrow$
  more frequent adoption, faster growth via within-firm productivity gains.

2. Subtle welfare effects.

- Loss of domestic variety from exit and increased "investment" versus benefits from faster growth.

Our Contributions

1. New mechanism linking trade and growth.

- Distinct from cross-country technology diffusion or market size effects.
- Only market size effects: trade does not affect firms' technology choice.
- Broader than trade. Our mechanism links competition and adoption.

2. Speaks to evidence that import competition leads to within-firm productivity or "X-efficiency" gains.

- Evidence: Pavcnik (2002), Topalova and Khandelwal (2011), Bloom, Draca, and Reenen (2011), etc.
- Explanations: Intermediates (Goldberg, Khandelwal, Pavcnik, and Topalova (2010)), product mix (Bernard, Redding, and Schott (2011)).
- Again, broader than trade, e.g., Holmes and Schmitz (2010).

Model: Time, Countries, and Consumers

Continuous time, infinite horizon economy.

N symmetric countries

Consumers with period utility:

$$U_i(t) = \int_t^\infty e^{-\rho(\tau - t)} \log C_i(\tau) d\tau$$

$$C_i(t) = \left(\sum_{j=1}^{N} \int_{\Omega_{ij}(t)} Q(v,t)^{\frac{\sigma-1}{\sigma}} dv \right)^{\frac{\sigma}{\sigma-1}}.$$

- $\rho =$ discount factor.
- $\Omega_{ij}(t) =$ varieties consumed.
- $\sigma =$ elasticity of substitution across varieties.

Consumers inelastically supply L units of labor.

Model: Firm's Technology

Large pool of monopolistically competitive firms in each country.

Firms are. . .

- Heterogeneous over productivity, Z.
- Sole producers of variety, v.
- Have linear production technologies using labor, ℓ,

$$Q = Z\ell.$$

- Face fixed cost and iceberg trade costs to export.
- Have the option to pay a cost and receive a new productivity draw.

Overview of Firm's Optimization Problems

Firm decisions can be divided into static and dynamic optimization problems and the entry and exit decisions.

Static Problem: Produce and Export...

Given Z, choose price and labor to maximize profits Π_{ji}, for each market j.

- Fixed costs to export to foreign market
- Iceberg trade costs to ship goods abroad

Very standard. I won't go through this today.

Overview of Firm's Optimization Problems

Firm decisions can be divided into static and dynamic optimization problems and the entry and exit decisions.

Dynamic Problem. . .

Incumbent firms' technology adoption: Given profits, choose **when** to upgrade technology, Z.

- Draw new productivity Z, related to **equilibrium** distribution $\Phi(Z, t)$.
- $X(t)$ is the cost (in units of labor) of drawing a new productivity.

Overview of Firm's Optimization Problems

Firm decisions can be divided into static and dynamic optimization problems and the entry and exit decisions.

Entry and Exit...

- Entrants receive initial productivity from $\Phi(Z, t)$ at cost $\frac{X(t)}{\chi}$, where $0 < \chi < 1$.
- Exit at exogenous rate δ.

For analytical tractability study the limiting case of $\delta \to 0$.

- Implies there is no exit and, hence, no entry.
- However, the equilibrium number of varieties/firms, Ω_{ii}, is endogenous.

The Firm's Dynamic Problem

For a small Δ period of time, given a forecasted sequence of $\Pi(t)$, $W(t)$, $P(t)$, and $\Phi(Z,t)$, the value of the firm is:

$$V(Z,t) = \max\left\{\Pi(Z,t)\Delta + \frac{1}{1+r\Delta}V(Z,t+\Delta)\ ,\ \tilde{V}_s(t) - X(t)\right\}$$

where

- $\tilde{V}_s(t) =$ expected value of new productivity draw.
- $X(t) =$ cost paid to draw new productivity

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Key issue: $\tilde{V}_s(t)$ relates to the domestic productivity distribution.

- If a firm upgrades, it receives a randomly drawn technology of a non-adopting firm in the domestic productivity distribution.

The Value of Adoption, $\tilde{V}_s(t)$

In equilibrium, a firm's optimal technology adoption policy is a reservation productivity function, $M(t)$.

To make this choice,

- Firms must forecast the minimum productivity level of a non-adopting firm, $\hat{Z}$, since firms receive a draw only from producers.
- Firms must forecast $\Phi(Z, t|Z > \hat{Z}(t))$.

Thus, the expected value of a productivity draw at t is

$$\tilde{V}_s(t) := \int V(Z, t) d\Phi(Z, t|Z > \hat{Z}(t)).$$

With rational expectations, $M(t) = \hat{Z}(t)$ in equilibrium.

Summary of a Firm's Dynamic Problem

1. The value function in the continuation region

$$r(t)V(Z,t) = \Pi(Z,t) + \frac{\partial V(Z,t)}{\partial t}$$

2. Value matching condition

$$V(M(t),t) = \tilde{V}_s(t) - X(t)$$

3. Smooth pasting condition

$$\frac{\partial V(M(t),t)}{\partial Z} = 0$$

4. Free Entry Condition

$$\frac{X(t)}{\chi} = \int_{M(t)}^{\infty} V(Z,t)d\Phi(Z,t)$$

Law of Motion for the Productivity Distribution

The law of motion for productivity distribution evolves according to the following Kolmogorov forward equation (KFE):

$$\frac{\partial \phi(Z,t)}{\partial t} = M'(t)\phi(M(t),t)\phi(Z,t).$$

A solution to this is a truncation for **any** $M(t)$ and $\Phi(0)$

$$\phi(Z,t) = \frac{\phi(Z,0)}{1-\Phi(M(t),0)}$$

The idea: The distribution at date t is a truncation of the initial distribution at the reservation adoption productivity.

The Initial Productivity Distribution

Assumption 1

The initial distributions of productivity are Pareto,

$$\Phi(Z,0) = 1 - \left(\frac{M(0)}{Z}\right)^{\theta} \quad \text{with density} \quad \phi(Z,0) = \theta M(0)^{\theta} Z^{-1-\theta}.$$

Lemma 1

Assumption # 1 and the solution to the KFE implies

$$\phi(Z,t) = \theta M(t)^{\theta} Z^{-1-\theta}.$$

If the initial density is Pareto with shape θ, it remains Pareto with shape θ.

Plan of Attack

Compute the Balanced Growth Path equilibrium.

Then ask some questions...

1. How do changes in variable trade costs affect growth?
2. What is happening at the firm level?
3. What is the role of reallocation vs. market size effects?
4. How do changes in variable trade costs affect welfare?
5. Quantitative exercise to evaluate magnitudes.

Computing the BGP

Normalize everything by the minimum of support, $M(t)$, so normalized objects are lower case.

Solve the value function using the smooth pasting as the boundary value.

- Value function depends on z, g, and Ω_{ii}.

Value function + value matching condition provides one equation in g and Ω_{ii}

Value function + the free entry condition gives second equation in g and Ω_{ii}.

All other endogenous variables pinned down given g and Ω.

The Balanced Growth Path

Proposition 1 (**Growth on the BGP**)

Given parametric assumptions and parameter restrictions, there exists a unique Balanced Growth Path Equilibrium with growth rate

$$g = \frac{\rho(1-\chi)}{\chi\theta}\frac{\bar{\pi}}{\bar{\pi}_{\text{min}}} - \frac{\rho}{\chi\theta},$$

where

- $\bar{\pi}$ = profits of the average firm.
- $\bar{\pi}_{\text{min}}$ = profits of the marginal, just adopting firm.
- And the profit ratio has the closed form expression

$$\frac{\bar{\pi}}{\bar{\pi}_{\text{min}}} = \frac{\left(\theta + (N-1)(\sigma-1)d^{-\theta}\left(\kappa\frac{\chi}{\rho(1-\chi)}\right)^{1-\frac{\theta}{\sigma-1}}\right)}{(\theta-\sigma+1)}.$$

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where

- $\bar{\pi} =$ profits of the average firm.
- $\bar{\pi}_{\text{min}} =$ profits of the marginal, just adopting firm.

Key feature: Growth encodes the trade-off that firms' face in a simple way:

Expected benefits (average profits) vs. the opportunity cost (forgone profits).

Proposition 2 (**Comparative Statics: Trade, Profits, and Growth**)

A decrease in variable trade costs...

1. Decreases a country's home trade share

$$\varepsilon_{\lambda_{ii},d} \;=\; \theta(1-\lambda_{ii}) \;>\; 0.$$

2. Increases the spread in profits between the average and marginal firm

$$\varepsilon_{\bar{\pi}_{\text{rat}},d} \;=\; \left(\frac{-(\sigma-1)}{1+\lambda_{ii}(\theta-1)}\right)\varepsilon_{\lambda_{ii},d} \;<\; 0.$$

3. Increases economic growth

$$\varepsilon_{g,d} \;=\; \left(\frac{\chi(1+\theta-\sigma)}{(\sigma-1)(1-\chi)}\lambda_{ii}-1\right)^{-1}\varepsilon_{\lambda_{ii},d} \;<\; 0.$$

Proposition 3 (**Firms and Technology Adoption**)

Given an aggregate growth rate g ...

1. The time $\tau(z)$ until an individual firm adopts is

$$\tau(z) = \frac{\log(z)}{g}.$$

2. The average time until adoption is

$$\bar{\tau} = \frac{1}{\theta g}.$$

3. Over a Δ length of time, the mass of firms that adopt is

$$\frac{\Delta}{\bar{\tau}} = \Delta \theta g.$$

Firms and Technology Adoption: Distinctions Relative to Literature

Theoretically distinctions. . .

- Atkeson and Burstein (2010), Bustos (2011): high productivity, exporting firms innovate more; low productivity, import-competing firms innovate less.
- Sampson (2015): all the change in growth comes through entry.

Firms and Technology Adoption: Empirical Implications

Empirical implications. . .

- Projections of openness measures on within-firm growth should find positive relationship.
- Distinct predictions for who responds—low productivity firms are those that change; high productivity firms do not.

Supporting evidence. . .

- Steinwender (2015), in Spanish data, find the least productive, import-competing firms increasing their productivity the most.
- Lileeva and Trefler (2010). New Canadian exporters experienced productivity gains, existing exporters did not. Largest gains for the least productive.

Proposition 4 (**Growth with No Selection into Exporting**)

In the model with $\kappa = 0$ and all firms selling internationally, the growth rate is

$$g \;=\; \frac{\rho(1-\chi)}{\chi\theta}\frac{\bar{\pi}}{\bar{\pi}_{\text{min}}} \;-\; \frac{\rho}{\chi\theta},$$

where the ratio of average profits to minimum profits is

$$\frac{\bar{\pi}}{\bar{\pi}_{\text{min}}} = \frac{\theta}{1+\theta-\sigma}.$$

Without reallocation effects, trade has no impact on growth.

Proposition 5 (**Variety, Labor, and Consumption**)

A decrease in variable trade costs...

1. Reduces domestic varieties.

$$\varepsilon_{\Omega,d} = \left(1 - \frac{1+\theta-\sigma}{\theta\sigma(1-\chi)}\lambda_{ii}\right)^{-1} \varepsilon_{\lambda_{ii},d} > 0.$$

2. Reduces the share of workers in goods production.

$$\varepsilon_{\tilde{L},d} = \left(\frac{\theta\sigma(1-\chi)}{1+\theta-\sigma}\lambda_{ii}^{-1} - 1\right)^{-1} \varepsilon_{\lambda_{ii},d} > 0.$$

3. And the total effect on consumption being negative.

$$\varepsilon_{c,d} = \varepsilon_{\tilde{L},d} + \frac{\varepsilon_{\Omega,d} - \varepsilon_{\lambda_{ii},d}}{\sigma - 1} < 0.$$

Proposition 6 (**Welfare Effects**)

The change in utility from a change in trade costs is

$$\varepsilon_{\bar{U},d} = \frac{\rho^2}{\bar{U}} \left(\rho \; \varepsilon_{c,d} + g \; \varepsilon_{g,d}\right).$$

Welfare depends on competing forces. . .

- Loss in consumption from less varieties, more “investment” in technology adoption.
- Faster economic growth.

Calibration

Calibration

Parameter	Value	Source or Target
Number of Countries, N	10	Normalization
Technology Adoption Cost, ζ	1.0	Normalization
Curvature Parameters, σ	3.0	—
Discount Rate, ρ	0.02	—
Iceberg Trade Cost, d	4.04	23.2 percent aggregate trade share
Export Fixed Cost, κ	0.01	20 percent of establishments export
Pareto Shape Parameter, θ	3.18	Exporters domestic shipments 4.8 $\times$ non-exporters
Entry Cost Relative to Adoption Cost $1/\chi$	2.18	Two percent growth rate

Welfare Gains From Trade

	Autarky	Baseline	Change (in %)
Growth	1.39	2.00	43.8
Initial Consumption Level	2.70	2.49	-7.78
Labor in Production	0.82	0.78	-4.88
Domestic Variety	2.00	1.71	-14.5
"ACR" Effect	1.00	1.14	14.0
Welfare	—	—	13.3
Consumption Equivalent	—	—	23.9

More Micro Implications

Extend the model to include firm level productivity shocks.

Study the model-implied dynamics of a firm. . .

1. Find that our model is quantitatively consistent with aspects of the observed persistence in relative productivity.
2. The role of within firm effects versus reallocation in accounting for aggregate productivity growth.

Conclusion

New perspective on trade and economic growth...

Very sharp characterization of growth as a function of statistics of the profit distribution—the ratio of profits between the average and marginal firm.

Reallocation effects of a trade liberalization lead to dynamic growth effects via within-firm productivity improvements.

- Distinct from traditional market size effects,
- Consistent with evidence on within-firm productivity effects from import competition,
- Subtle welfare consequences.