International Trade and Macro:
Calibrating sunk-cost models (and GE)

Success and Challenges

- Successes
  - Persistent export participation (fact #1)
  - Low export and entry rates (facts #3,4)
  - Dynamic macro adjustment (fact #7)
- Challenges
  - New exporters (too productive at entry, too likely to continue, export intensity too high)
  - Connection in exporting across markets
  - High re-entry rates in monthly and longer frequencies
- Causes
  - Exporting technology too simple (parsimonious): f_0, f_1, ξ
  - Need to shift more investment into post-entry period and reduce depreciation

Micro exporter facts

1. Not all plants export (22% in US)
2. Exporters are relatively large (5x larger)
3. Exporting is persistent (83% survival)

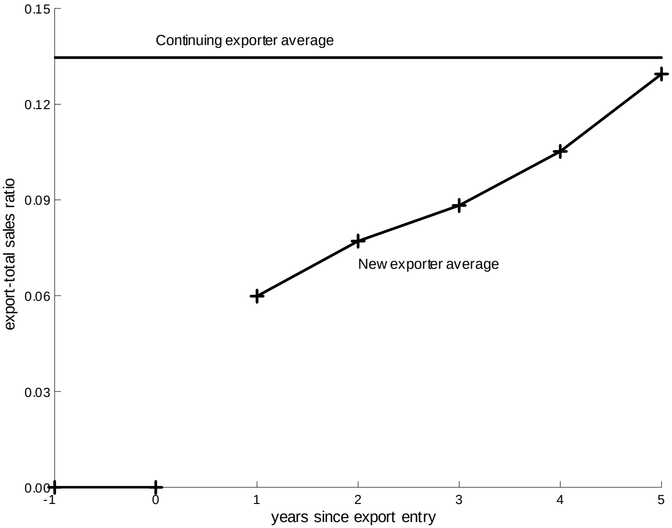
Micro exporter facts

1. Not all plants export (22% in US)
2. Exporters are relatively large (5x larger)
3. Exporting is persistent (83% survival)
4. New exporters start with low *export intensity*

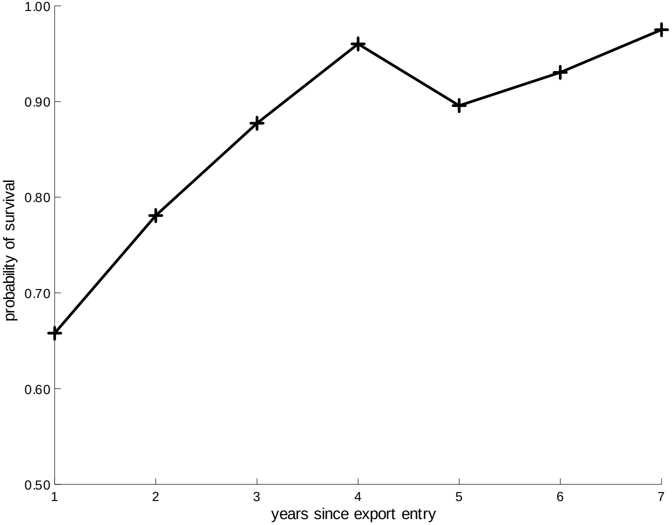
$$\text{exs}_{it} = \text{exports}_{it}/\text{total sales}_{it}$$

5. New exporters take time (5yrs) to get to average exporter levels
6. New exporters have high exit rates

Export intensity of Colombian exporters (Ruhl & Willis, 17)



Survival probability of Colombian new exporters (Ruhl & Willis, 17)



Today's goals

1. Focus on fixing the new exporter dynamics.
   In standard sunk-cost model, new exporters are (compared to data)
   - Too productive $\rightarrow$ too big
   - Export too much
   - Too likely to continue
2. Embed the firm choice problem into GE
3. Discuss calibration
4. Quantitative analysis of trade liberalization. Do exporter life cycles matter?
5. Other ways to add exporter life cycle dynamics

- Will largely follow Alessandria et al. (2021)

Model

- General equilibrium, infinite horizon, 2 country $\{H, F\}$ model
- Idiosyncratic uncertainty, no aggregate uncertainty
- Heterogeneous plants producing differentiated tradable goods
  - Monopolistic competitors
  - Fixed export costs: startup and continuation
  - Plants are created: endogenous mass of firms
- Exporter life cycle: time to build demand/lower marginal export costs
- Final C/I good combines available differentiated tradables

Model

- Mass N_t, N_t^* differentiated H & F intermediates
- Each variety produced by 1 domestic-owned establishment
  - Idiosyncratic technology shocks: z, $\phi(z'|z)$
  - Fixed export cost: $f = \{f_H, f_L\}$ (paid in labor)
  - Iceberg costs: $\xi = \{\xi_L, \xi_H, \infty\}$
  - Establishment's state: $s = (z, \xi, f)$
  - Measure of establishments: $\varphi_{i,t}(z, \xi, f)$

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  - Establishment's state: $s = (z, \xi, f)$
  - Measure of establishments: $\varphi_{i,t}(z, \xi, f)$
- Free entry: hire f_E workers, draw $\phi_E(z)$ in $t+1$
- Exogenous survival: $n_s(z)$
- Timing: fixed costs paid 1 period in advance

Exporting technology

- A nonexporter
  - In current period: $\xi = \infty$
  - Can pay $f = f_H$ to begin exporting next period
  - If so, in next period: $\xi' = \xi_L$

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- An exporter
  - In current period: $\xi < \infty$
  - Can pay $f = f_L$ to continue exporting
  - If so, in next period: draw ξ' w prob. $\rho_\xi\left(\xi'|\xi\right)$
  - If not: exit raises cost to ∞

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- Our model: $\xi_H > \xi_L$, $f_H > f_L$
  - Das, Roberts, Tybout (2007): $\xi_H = \xi_L$, $f_H > f_L$
  - Ghironi and Melitz (2005): $\xi_H = \xi_L$, $f_H = f_L$
  - Krugman (1980) w/heterogeneity: $\xi_H = \xi_L$, $f_H = f_L = 0$

Consumer's problem

$$V_{C,0} = \max_{\{C_t, B_t, K_{t+1}\}} \sum_{t=0}^{\infty} \beta^t U(C_t)$$

$$C_t + K_{t+1} + Q_t \frac{B_t}{P_t} \leq W_t L_t + R_t K_t + (1-\delta) K_t + \Pi_t + T_t + \frac{B_{t-1}}{P_t},$$

- P_t, W_t denote price level & real wage
- Π_t sum of home country profits, T_t lump sum gov't transfers
- Foreign problem is analogous; foreign variables denoted by *

$$\begin{aligned} Q_t &= \beta \frac{U_{C,t+1}}{U_{C,t}} = \beta \frac{U^*_{C,t+1}}{U^*_{C,t+1}}, \\ 1 &= \beta \frac{U_{C,t+1}}{U_{C,t}} (R_{t+1} + 1 - \delta) = \beta \frac{U^*_{C,t+1}}{U^*_{C,t}} \left(R^*_{t+1} + 1 - \delta\right) \end{aligned}$$

Competitive final good producers

- Combine domestic and imported intermediates, produce goods for
  - Consumption, investment, and intermediate use

$$D_t = \left[\int_s y_{H,t}^d(s)^{\frac{\theta-1}{\theta}} \varphi_{H,t}(s)\, ds + \int_s y_{F,t}^d(s)^{\frac{\theta-1}{\theta}} \varphi_{F,t}(s)\, ds \right]^{\frac{\theta}{\theta-1}}$$

$$D_t = C_t + I_t + \int_s x(s) \varphi_{H,t}(s)\, ds$$

- Representative firm maximizes

$$\Pi_t = D_t - \int_s P_{H,t}(s)\, y_{H,t}^d(s)\, \varphi_{H,t}(s)\, ds - (1+\tau) \int_s P_{F,t}(s)\, y_{F,t}^d(s)\, \varphi_{F,t}(s)\, ds$$

- Generates standard input demand functions
- τ is a policy

Tradable producers

- Individual state is $s = (z, \xi, f)$

- Production Technology: $y_t(s) = e^z \left[k_t(s)^\alpha \, l_t(s)^{1-\alpha}\right]^{1-\alpha_x} x(s)^{\alpha_x}$

- Profit, $\Pi_t(s)$, is

$$\max_{P_H, P_H^*, l, k, x} P_{H,t}(s)\, y_{H,t}(s) + P_{H,t}^*(s)\, y_{H,t}^*(s) - W_t l_t(s) - R_t k_t(s) - P_t x_t(s)$$
$$\text{s.t.} \;\; y_t(s) = y_{H,t}^d(s) + (1+\xi)\, y_{H,t}^{d*}(s),$$

Export decision

$$V_t\left(z,\xi,f\right)=\max\left\{V_t^1\left(z,\xi,f\right),V_t^0\left(z,\xi,f\right)\right\}$$

$$\begin{aligned}V_t^1\left(z,\xi,f\right)=&\max\Pi_t\left(z,\xi,f\right)-W_tf\\&+n_s\left(z\right)Q_t\sum_{\xi'\in\{\xi_L,\xi_H\}}\int_{z'}V_{t+1}\left(z',\xi',f_L\right)\phi\left(z'|z\right)dz'\rho_\xi\left(\xi'|\xi\right)\end{aligned}$$

$$\begin{aligned}V_t^0\left(z,\xi,f\right)=&\max\Pi_t\left(z,\xi,f\right)\\&+n_s\left(z\right)Q_t\int_{z'}V_{t+1}\left(z',\infty,f_H\right)\phi\left(z'|z\right)dz'\end{aligned}$$

- With 3 iceberg costs there are three marginal firm types

Free entry

- Hire f_E workers to enter

- Draw technology $\phi_E(z)$, produce in $t+1$

$$V_t^E = -W_t f_E + Q_t E V_t(z, \infty, f_H)\,\phi_E(z) \leq 0$$

$\Rightarrow N_{TE,t}$ new establishments

Trade

- No simple relationship between parameters and trade elasticity
- Trade depends on tariff and distribution of plant types $\phi_{it}(z, \xi, f)$
- Lower tariff: increases export participation
- Lower tariff: increases duration in exporting, lowering ξ

Calibration strategy

- Calibrate to the United States in 1990s (matters mostly for tariff level)
- Calibrate the stationary steady state of the model to averages from the data
- Some parameters from the literature
- Some parameters computed without solving the model eq'm
- Some parameters computed needing to solve the model eq'm

- Part of research is knowing which parameters are in which set.
  This is somewhat field specific.

Calibration: from the literature or without full solution

- Utility: $U(c) = \frac{c^{1-\sigma}}{1-\sigma}$

σ	IES	2
δ	Capital depreciation	0.10
β	Disounting	0.96
θ	Elasticity of substitution	5
τ	Tariff (Anderson and van Wincoop)	0.1
α_x	MFR gross output/MFR VA $= 2.8$	0.81
α	Capital share of income $= 34\%$	0.13

Calibration: simulated method of moments

- Productivity

$$z' = \rho z + \epsilon \qquad \epsilon \sim N(0, \sigma_\epsilon^2)$$

- Initial productivity

$$z' = -\mu_E + \epsilon_E \qquad \epsilon_E \sim N\left(0, \frac{\sigma_\epsilon^2}{1-\rho^2}\right)$$

- Probability of exit

$$1 - n_s(z) = \max\{0, \min\{e^{-\lambda z} + n_{d0}, 1\}\}$$

- Export costs: two state Markov $\rho_{LL} = \rho_{HH}$
- Parameters $\left(f_L, f_H, \xi_L, \xi_H, \rho_{HH}, \lambda, n_{d0}, \mu_E, \rho, \sigma_\epsilon^2\right)$

Calibration: Establishment data

A. Exporter dynamics and characteristics:

0. Overall export intensity = 13%

1. Overall participation rate = 22.3 % (92 Census of Mfrs.)

2. Stopper rate = 17 % (ASM)

3. Initial export intensity 1/2 of avg. intensity (Ruhl&Willis 17)

4. 5 years to reach avg export intensity (Ruhl&Willis 17)

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B. Establishment heterogeneity:

5. Entrant 5-yr survival 37 % (Dunne et al. 89)

6. Birth labor share =1.5 % (Davis, et al. 96)

7. Exit labor share = 2.3 % (Davis, et al. 96)

8. Establishment and employment distribution (92 Census)

9. Establishment exporter distribution (92 Census)

Identification

- No clean identification: Everything effects everything (GE curse), but...
- (ξ_L, ξ_H, ρ_ξ) Exporter life cycles
  - mean export intensity
  - initial export intensity half the mean
  - five-year export intensity twice initial intensity
- (f_L, f_H) Export entry and exit
  - export stopper rate
  - export participation rate
- $(\rho, \sigma_\epsilon, \lambda, n_{d0}, \mu_E)$ Firm creation and dynamics
  - new-firm share of total labor
  - five-year exit rate of new firms
  - shut-down firm share of total labor

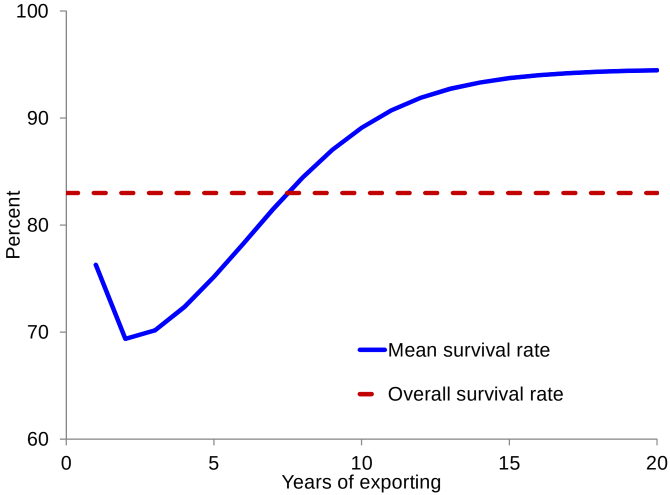
Estimates of export technology

Estimate of benchmark export technology

- Entry cost 40% larger than continuation cost: $f_H/f_L = 1.4$
- High iceberg cost 62% larger than low iceberg cost (1.72 vs. 1.07)
- Iceberg cost very persistent: $\rho\left(\xi_H|\xi_H\right) = 0.92$

	Benchmark	Sunk-cost
f_H/f_E	0.038	
f_L/f_E	0.027	
ξ_H	1.718	
ξ_L	1.070	
ρ_ξ	0.916	

1-year survival rate (not targeted)



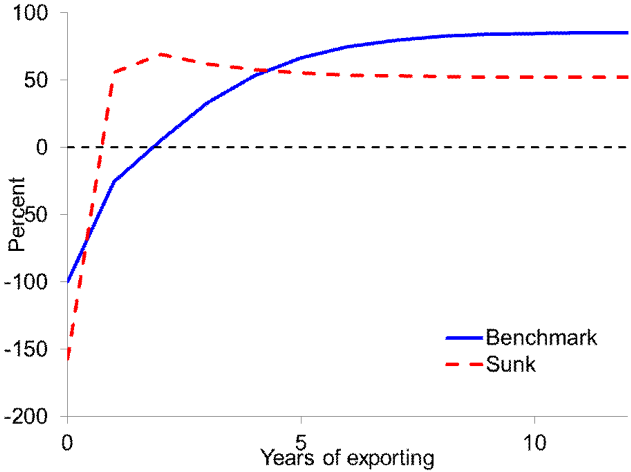
Alternative model: Sunk cost export technology

- Restriction: $\xi_H = \xi_L$
- Re-estimate, drop new exporter dynamic moments

	Benchmark	Sunk-cost
f_H/f_E	0.038	0.058
f_L/f_E	0.027	0.015
ξ_H	1.718	1.430
ξ_L	1.070	1.430
ρ_ξ	0.916	1.000

- $f_H/f_L = 3.9$ vs. $f_H/f_L = 1.4$ in benchmark
- In benchmark model, high survival rate arises because producers don't want to go through growth process again — not sunk costs.

Profits of marginal starters: $\left(E\pi_{x,t} - f\right) / f_H^{bench}$

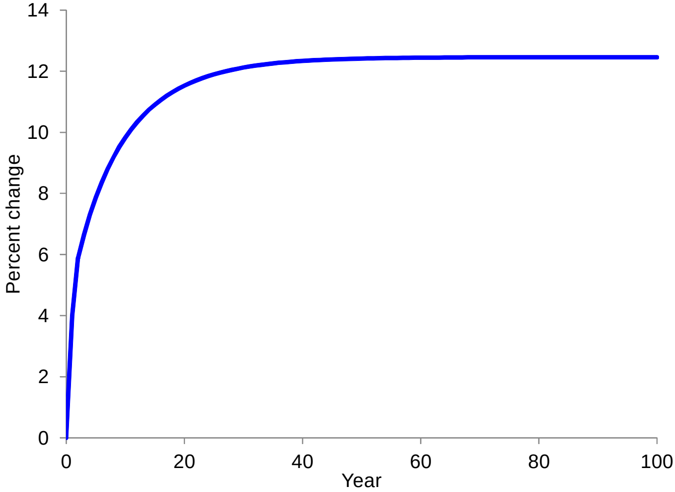


Three experiments

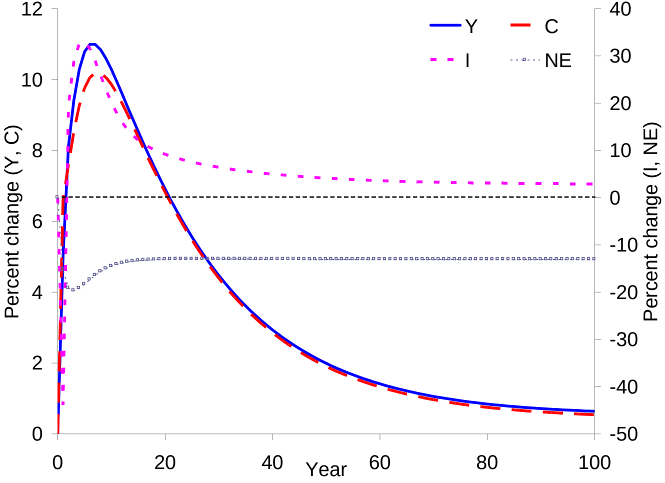
1. Benchmark: $\xi_H > \xi_L$, $f_H > f_L$
2. Sunk cost: $\xi_H = \xi_L$, $f_H > f_L$
3. No cost: $\xi_H = \xi_L$, $f_H = f_L = 0$

- Consider unanticipated global tariff reduction, $\tau = 0.1 \rightarrow \tau = 0$

Dynamics following elimination of 10 percent tariff
Benchmark Model: Trade elasticity



Dynamics following elimination of 10 percent tariff
Benchmark Model: Aggregate dynamics



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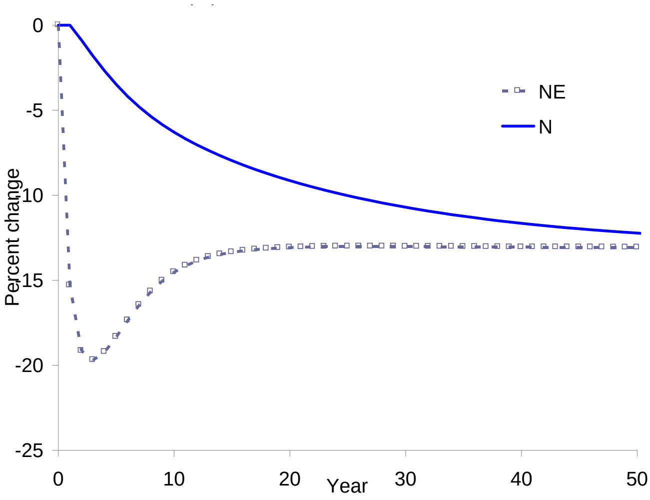


Welfare and trade in the benchmark model

Change	Benchmark	Sunk-cost	No-cost
Welfare gain	6.30		
Avg. trade elasticity ($\bar{\varepsilon}_t$)	10.2		
Δ SS. Consumption	0.42		
SS. Trade elasticity	11.5		

Welfare gain is x: $\sum_{t=0}^{\infty} \beta^t U(C_{-1} e^x) = \sum_{t=0}^{\infty} \beta^t U(C_t)$

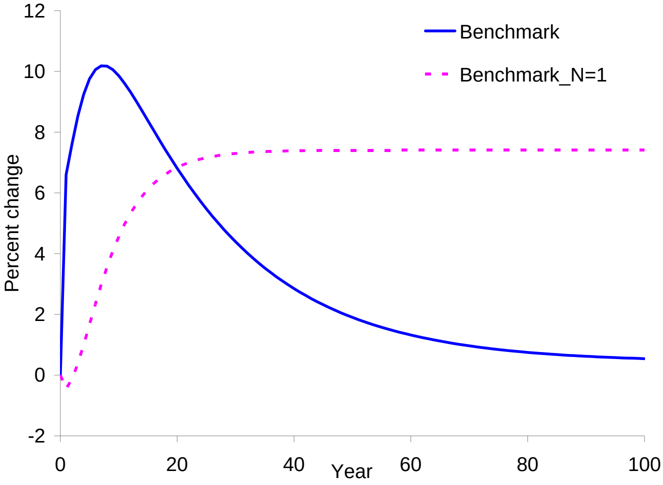
$$\bar{\varepsilon}_t = (1-\beta) \sum_{t=0}^{\infty} \beta^t \varepsilon_t$$

Source of overshooting

- Tariffs lead to an overaccumulation of establishments relative to free trade steady state
- These establishments can be converted at a low cost to exporters
- Labor that would have gone to firm creation goes to production

- Experiment: subsidize entry so that $N_t = 1$

Dynamics following elimination of 10 percent tariff
Aggregate Output



The sunk-cost model

- Literature has focused on sunk costs as a source of persistent exporting
- Sunk cost model misses out on aspects of new exporter dynamics.
- Ask: How well does this simpler dynamic model of exporter approximate trade/welfare predictions of the benchmark model?

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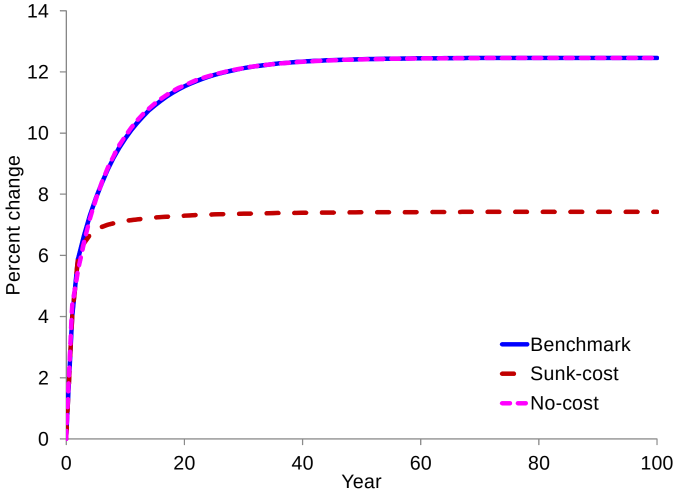
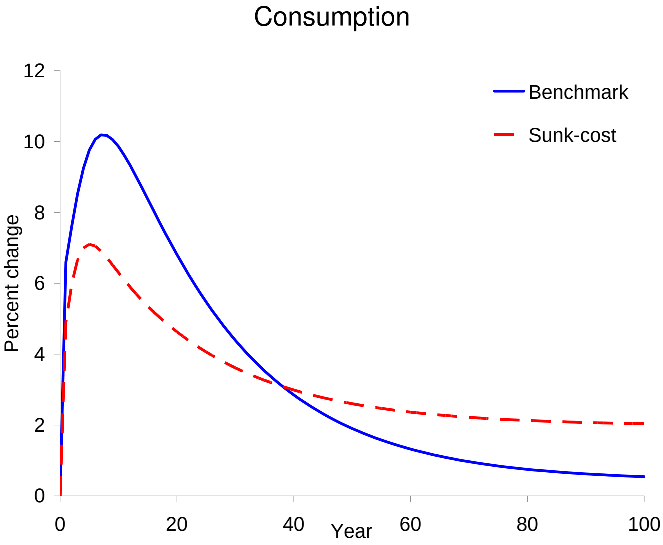
- Sunk cost model misses out on aspects of new exporter dynamics.
- Ask: How well does this simpler dynamic model of exporter approximate trade/welfare predictions of the benchmark model?
- Answer: Not so good on trade, pretty good on consumption/welfare

Trade elasticity





Consumption
12
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Percent change
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20
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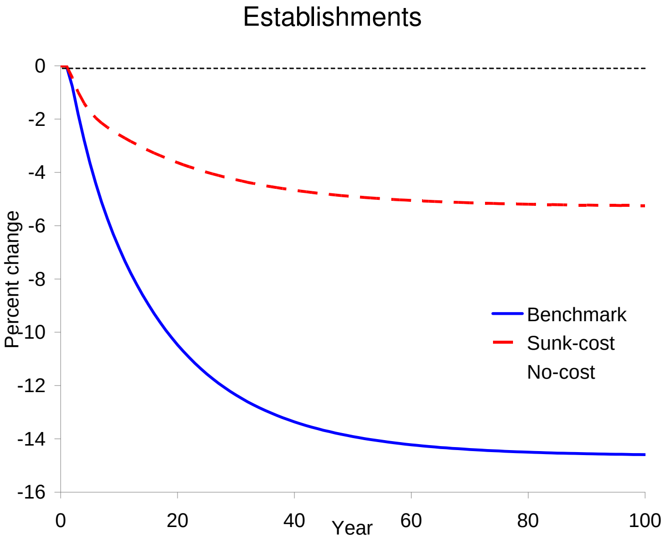
100
Year
Benchmark
Sunk-cost


Establishments
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Welfare and trade in the sunk-cost model

Change	Benchmark	Sunk-cost	No-cost
Welfare gain	6.30	4.75	
Avg. trade elasticity ($\bar{\varepsilon}_t$)	10.2	6.9	
Δ SS. Consumption	0.42	1.98	
SS. Trade elasticity	11.5	7.2	

Welfare gain is x: $\sum_{t=0}^{\infty} \beta^t U(C_{-1} e^x) = \sum_{t=0}^{\infty} \beta^t U(C_t)$

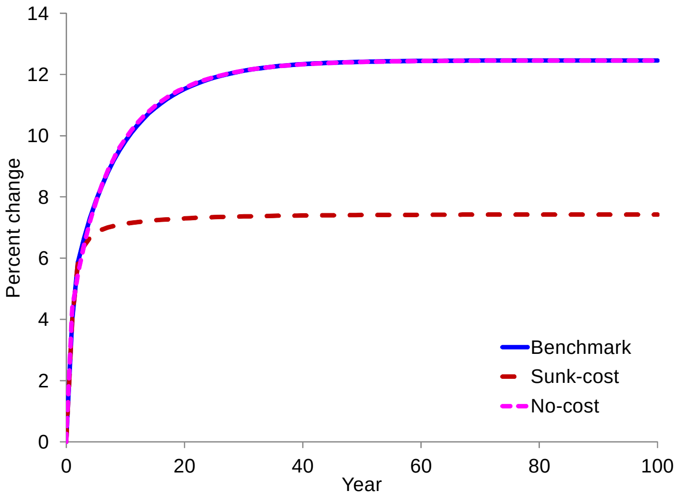
$$\bar{\varepsilon}_t = (1-\beta) \sum_{t=0}^{\infty} \beta^t \varepsilon_t$$

How important is endogenous exporting?

- Krugman (1980): all firms export

- Requires two main changes
  1. Change θ to get LR trade elasticity
  2. Add adjustment friction to get dynamics of trade elasticity

Trade elasticity



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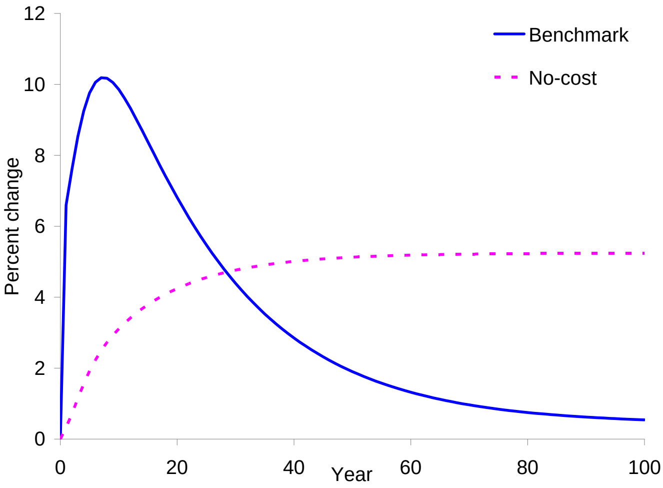

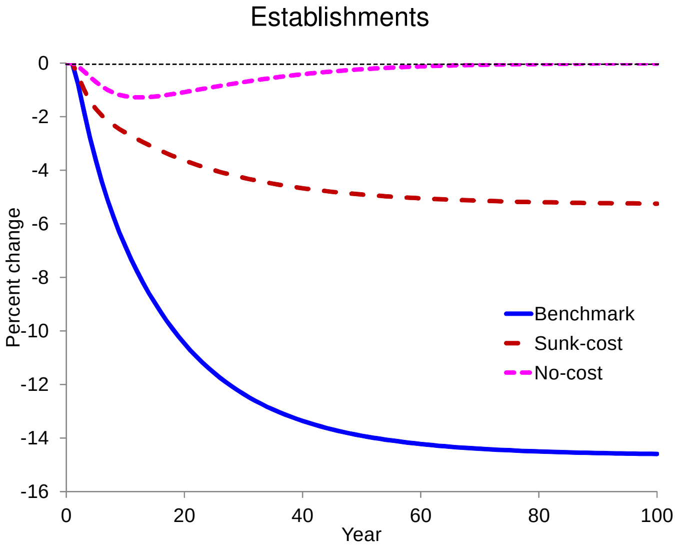

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$$\bar{\varepsilon}_t = (1-\beta) \sum_{t=0}^{\infty} \beta^t \varepsilon_t$$

Modeling export intensity dynamics

Export intensity dynamics

- We took a simple approach. Better micro-founded models…
- Accumulate customers or build habit
- Let's sketch out the ideas

Customer-acquisition models of exporter dynamics

- Demand for firm's product depends on price (p), trade cost (τ), and customer base (m):

$$d(p, m; \tau) = (p\tau)^{-\theta} m^{\alpha}$$

  - α governs diminishing returns to having more customers
- Firms heterogeneous in productivity (z)
- Assume constant-markup pricing so that flow profits from exporting given by

$$\pi(z, m; \tau) \propto (z/\tau)^{1-\theta} m^{\alpha}$$

- Firm's problem: choose to export/not export to maximize PDV of profits—and possibly, choose how many customers to acquire
- Q: How to model customer aquisition?

Customer-acquisition models of exporter dynamics

- Fitzgerald et al. (2019, 2021): Quadratic adjustment cost
- Piveteau (2020): Word-of-mouth
- Steinberg (2021): Dynamic version of Arkolakis (2010)
- Customer acquisition in other contexts
  - Arkolakis (2010), EKK (2011): static models of how/why exporter distribution varies across bilateral trade relationships
  - Drozd-Nosal (2021): pricing to market, int'l macro puzzles
- Many other papers in which firms initially charge low prices to attract customers; focus on constant-markup models today
  - See Fitzgerald et al. (2019, 2021) for good review of both approaches

Fitzgerald et al. (2019, 2021)

- Pay sunk cost s to start exporting with $\underline{m}$ initial customers (exogenous)
- Pay fixed cost f to continue exporting; if not, lose all customers
- Customer base depreciates at rate δ, grows by investment a

$$m' = (1-\delta)m + a$$

- Cost of investment:

$$c(m, a) = a + \phi a^2/m$$

- Dynamic program (V^0: potential exporter, V^1: incumbent):

$$V^0(z) = \max\left\{\mathbb{E}V^0(z'), \pi(z, \underline{m}; \tau) - f + \mathbb{E}V^1(z', \underline{m})\right\}$$
$$V^1(z) = \max\left\{\mathbb{E}V^0(z'), \max_m \left[\pi(z, (1-\delta)m + a; \tau) - s - c(m, a) + \mathbb{E}V^1(z', (1-\delta)m + a)\right]\right\}$$

Piveteau (2020)

- Pay sunk cost s to start exporting with $\underline{\text{m}}$ initial customers (exogenous)
- Pay fixed cost f to continue exporting; if not, lose all customers
- Customer base growth depends on sales and size of current customer base ("word of mouth")

$$m' = 1 - \{1 - \eta_1(1-\psi)pd(p, m; \tau) - \eta_2(1-\psi)m\}^{\frac{1}{1-\psi}} \in (0,1)$$

- No cost of investment (in paper firm can also grow customer base by charging lower prices, and therefore selling more than under constant-markup pricing)

$$V^0(z) = \max\left\{\mathbb{E}V^0(z'), \pi(z, \underline{\text{m}}; \tau) - f + \mathbb{E}V^1(z', \underline{\text{m}})\right\}$$
$$V^1(z) = \max\left\{\mathbb{E}V^0(z'), \pi(z, m'; \tau) - s + \mathbb{E}V^1(z', m')\right\}$$

Steinberg (2021): market penetration dynamics

- No sunk or fixed costs, initial customer base endogenous
- Customer base evolves according to $m' = n + o$, where
  - $n \in [0, 1-m]$: new customers attracted
  - $o \in [0, m]$ old customers retained
- Attraction/retention costs depend on current customer base:

$$a_n(m,n) = \frac{L^{\alpha_n}(1-m)^{\beta_n}}{\psi_n(1-\gamma_n)}\left[1 - \left(\frac{1-m-n}{1-m}\right)^{1-\gamma_n}\right]$$

$$a_o(m,o) = \frac{L^{\alpha_o} m^{\beta_o}}{\psi_o(1-\gamma_o)}\left[1 - \left(\frac{m-o}{m}\right)^{1-\gamma_o}\right]$$

- Given current customer base m, cost of getting to m' given by

$$f(m,m') = \min_{n,o}\ \{a_n(m,n) + a_o(m,o)\} \quad \text{s.t.} \quad 0 \le n \le 1-m, \quad 0 \le o \le m, \quad m' = n + o$$

Steinberg (2021): dynamic program

Value function:

$$V(z,m) = \max_{m'} \left\{ \pi(z,m') - f(m,m') + \frac{\delta(z)}{1+R} \mathbb{E}\left[V(z',m')|x,z\right] \right\}$$

Solution: $$\underbrace{f_2(m,m')}_{\text{marginal cost}} \geq \underbrace{\tilde{\pi} z^{\theta-1}}_{\text{marginal profit}} - \underbrace{\frac{\delta(z)}{1+R}\mathbb{E}\left[f_1(m',m'')|z\right]}_{\mathbb{E}[\downarrow] \text{ in future exporting cost}}$$

- If $m = 0$, enter if $z \geq \underline{z}$:

$$f_2(0,0) = \tilde{\pi} \underline{z}^{\theta-1} - \frac{\delta(z)}{1+R}\mathbb{E}\left[f_1(0,m'')|z\right]$$

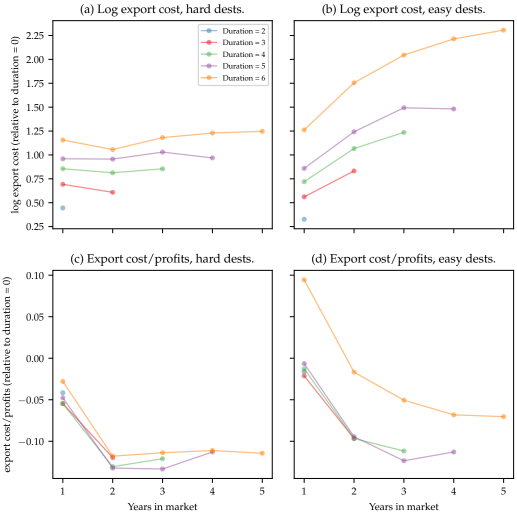
- If $m > 0$, exit if $m \leq \underline{m}(z)$:

$$f_2(\underline{m}(z),0) = \tilde{\pi} z^{\theta-1} - \frac{\delta(z)}{1+R}\mathbb{E}\left[f_1(0,m'')|z\right]$$

Steinberg (2021): key properties

- $f_2(m, 0) > 0$: marginal cost of serving a single customer strictly positive $\Rightarrow$ entry + exit
- $f_{22}(m, m') > 0$: MC increasing in size of new customer base $\Rightarrow$ concentration
- $f_{21}(m, m') < 0$: MC decreasing in size of initial customer base $\Rightarrow$ new exporter dynamics
  - $f_2(0, m') > f_2(m, m')$: Entrant's MC curve entrants higher than incumbent's $\Rightarrow$ entrants start small then grow
  - $f_2(0, 0) > f_2(m, 0)$: Entrant's MC of acquiring single new customer higher than incumbent's MC of keeping single old customer $\Rightarrow$ exit rate $\downarrow$ in m

Steinberg (2021): Calibrated exporting costs



Levels:

- Hard dests: flat w/ time in a market
- Easy dests: ↑ w/ time in a market
- Higher for more successful exporters

Relative to profits:

- ↓ w/ time in a market
- More pronounced ↓ in easy dests.
- $f_2(m, m')/(LY) \downarrow$ in $L, Y \Rightarrow$ variation in exporter dynamics across markets

Complementary investments

- Trade costs depend on what else the firm is doing
- Example: If I import from a country, it is easier for me to export to it

1. Destinations (Albornoz et al., 2012; Albornoz et al., 2016; Morales et al., 2019)
2. Importing and exporting (Kasahara and Lapham, 2013)
3. Importing, exporting and destinations (Li et al., 2023)

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