РАНХиГС
РОССИЙСКАЯ АКАДЕМИЯ НАРОДНОГО ХОЗЯЙСТВА
И ГОСУДАРСТВЕННОЙ СЛУЖБЫ
ПРИ ПРЕЗИДЕНТЕ РОССИЙСКОЙ ФЕДЕРАЦИИ

РАНХиГС
экономический
факультет

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R&D Investment, Exporting, and Productivity Dynamics

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Motivation:

Research question:

- Does openness to trade promote productivity?

Motivation:

Exports and firm productivity are correlated

- Selection: robust finding
- Learning-by-Exporting: mixed evidence

Interdependent R&D and exporting at firm-level

- Exporting → larger market → more R&D incentive
- Selection
- R&D → higher expected future productivity → re-inforce selection

Market size effect depend on

- domestic/exporting profitability
- innovation process
- costs assoicated with each activity

Literature

1. Empirics on exporting and productivity: Bernard and Jensen (1999); Bustos (2007)
2. Recent macro/trade models of joint decisions of R&D and export: Atkeson and Burstein (2008); Constantini and Melitz (2008)
3. Structural estimation of industry equilibrium: Olley and Pakes (1996): productivity dynamics; Das, Roberts and Tybout (2007): exporting with sunk and fixed costs
4. A reflection of a new mechanism: endogenous innovation? Bustos (2007), Lileeva and Trefler (2007): trade liberalization induces more innovation; Aw, Roberts, and Winston (2007): R&D and exporting correlated.

Theoretical Model

Technology:

• Short-run marginal cost:

$$lnc_{it} = lnc(k_{it}, w_t) - x_{it} = \beta_0 + \beta_k lnk_{it} + \beta_w lnw_t - x_{it}$$

• k_{it} capital stock, w_t variable input price, x_{it} productivity • Differs across firms, but not a function of output • Two sources of heterogeneity: capital-observable, productivity-not observable by researchers.

Theoretical Model

Demand:

• Demand for the firm's output in domestic market (Dixit -Stiglitz)

$$q_{it}^D = Q_t^D (p_{it}^D / P_t^D)^{\eta_D} = \frac{I_t^D}{P_t^D} \left(\frac{p_{it}^D}{P_t^D} \right)^{\eta_D} = \Phi_t^D (p_{it}^D)^{\eta_D}$$

• All aggregates are combined into Φ_t^D

• Similarly, demand for the firm's output in export market:

$$q_{it}^X = Q_t^X (p_{it}^X / P_t^X)^{\eta_X} = z_{it} \frac{I_t^X}{P_t^X} \left(\frac{p_{it}^X}{P_t^X} \right)^{\eta_X} = \Phi_t^X z_{it} (p_{it}^X)^{\eta_X}$$

• z_{it}: firm-specific demand shock in export market. Heterogeneity between export and domestic market for each firm.

Theoretical Model

- These assumptions imply domestic and export revenue function as:

$$lnr_{it}^{D} = (\eta_D + 1)ln(\frac{\eta_D}{\eta_D + 1}) + ln\Phi_t^D + (\eta_D + 1)lnc_{it}$$

$$lnr_{it}^{X} = (\eta_X + 1)ln(\frac{\eta_X}{\eta_X + 1}) + ln\Phi_t^X + (\eta_X + 1)lnc_{it} + z_{it}$$

- Profits: directly relate revenue to unobservables x_{it} and z_{it}.

$$\pi_{it}^{D} = (-1/\eta_D)r_{it}^{D}(\Phi_t^D, k_{it}, x_{it})$$

$$\pi_{it}^{X} = (-1/\eta_X)r_{it}^{X}(\Phi_t^X, k_{it}, x_{it}, z_{it})$$

Finally, total cost $tvc_{it} = r_{it}^{D}(1 + \frac{1}{\eta_D}) + r_{it}^{X}(1 + \frac{1}{\eta_X})$

Theoretical Model

• Productivity x_{it} evolves endogenously, depending on R&D d_{it-1} and exporting e_{it-1}:

$$x_{it} = g(x_{it-1}, d_{it-1}, e_{it-1}) + \psi_{it}$$

• d_{it-1}: learning-by-investing. e_{it-1}: learning-by-exporting. d, e: discrete (0/1) or continuous.

• Export demand shock z_{it} evolves exogenously as a first order markov process:

$$z_{it} = \rho_z z_{it-1} + \mu_{it}, \mu_{it} \sim N(0, \sigma_\mu^2$$

• Firm size measure capital k_i: short time series dimension with very little variation over time

Theoretical Model

Sources of dynamics:

• e and d affect evolution of future x; z is persistent over time

• Beginning each activity involves one-time sunk cost.

Sequence of Information and Decisions:

1. Begin period t with productivity and export demand shock (x_{it}, z_{it}).
2. Random fixed cost γ_{it}^F of exporting and sunk cost $\overset{S}{_{it}} \rightarrow$ export decision.
3. Maximize static profits π_{it}^D and, if exporting, π_{it}^X.
4. Random fixed cost of R&D γ_{it}^I and sunk cost $\gamma_{it}^D \rightarrow$ R&D decision.
5. End of period t, new states (x_{it+1}, z_{it+1}) realized.

Theoretical Model

- Let $s_{it} = (z_{it}, x_{it}, k_i, e_{it-1}, d_{it-1}, \Phi_t)$
- Firm's integrated value function in year t

$$V_{it}(s_{it}) = \int \pi_{it}^D + \max_{e_{it} \in (0,1)} \{\pi_{it}^X - e_{it-1}\gamma_{it}^F - (1 - e_{it-1})\gamma_{it}^S + V_{it}^E, V_{it}^D\} dG^{\gamma}$$

- Firm's future value of exporting:

$$\begin{aligned} V_{it}^E(s_{it}) \quad = \quad & \int \max_{d_{it} \in (0,1)} \{\delta E_t V_{it+1}(s_{it+1}|\cdot, e_{it} = 1, d_{it} = 1) - \gamma_{it}^I d_{it-1} \\ & -\gamma_{it}^D(1 - d_{it-1}), \delta E_t V_{it+1}(s_{it+1}|\cdot, e_{it} = 1, d_{it} = 0)\} dG^{\gamma^{I,D}} \end{aligned}$$

- Firm's future value when it chooses not to export:

$$\begin{aligned} V_{it}^D(s_{it}) \quad = \quad & \int \max_{d_{it} \in (0,1)} \{\delta E_t V_{it+1}(s_{it+1}|\cdot, e_{it} = 0, d_{it} = 1) - \gamma_{it}^I d_{it-1} \\ & -\gamma_{it}^D(1 - d_{it-1}), \delta E_t V_{it+1}(s_{it+1}|\cdot, e_{it} = 0, d_{it} = 0)\} dG^{\gamma^{I,D}} \end{aligned}$$

Theoretical Model

Firm's problem:

$$\max_{\{e_t,d_t\}} \left\{ E_0 \sum_{t=0}^{\infty} \delta^t \left\{ \pi^D(\omega_t) + e_t[\pi^X(\omega_t,z_t) - \gamma^X(e_{t-1})] - d_t\gamma^R(d_{t-1}) \right\} \right\}$$

subject to productivity evolution:

$$\omega_t = g(\omega_{t-1}, e_{t-1}, d_{t-1})$$

- No static optimization
- High ω_t affects incentives for both e_t and d_t
- Interactions between e_t and d_t through both objective function and productivity dynamics
- Persistence through sunk versus fixed costs (both iid): option value of waiting

Theoretical Model

- Finally, the expected future value conditional on different choices e_{it} and d_{it}:

$$E_t V_{it+1} = \int_{\Phi'} \int_{z'} \int_{x'} V_{it+1}(s_{it+1}) dF(x'|x_{it}, e_{it}, d_{it}) dF(z'|z_{it}) dG(\Phi'|\Phi_t)$$

- **Three mechanisms** that exporting and R&D are correlated:
  - Selection: probability of e_{it} and d_{it} increasing in x_{it} and z_{it}.
  - $MBD(s_{it}) = E_t V_{it+1}(\cdot|e_{it}, d_{it} = 1) - E_t V_{it+1}(\cdot|e_{it}, d_{it} = 0)$
    - export sunk cost γ_{it}^S
    - knowledge production $g(x_{it}, e_{it}, d_{it})$.
  - $MBE(s_{it}) = \pi_{it}^X + V_{it}^E(\cdot, d_{it-1}) - V_{it}^D(\cdot, d_{it-1})$
    - R&D sunk cost γ_{it}^D
    - knowledge production $g(x_{it}, e_{it}, d_{it})$.

Estimation

Static equations:

- $\{tvc_{it}, r^D_{it}, r^X_{it}\}$ to estimate elasticity of demand
- $\{r^D_{it}, k_{it}, m_{it}, n_{it}\}$ to estimate productivity ω_{it}
- $\{r^X_{it}, \omega_{it}\}$ to estimate export demand shock z_{it}

Productivity dynamics:

$$\omega_{it} = g(\omega_{it-1}, e_{it-1}, d_{it-1})$$

Estimated by OLS using a parametric assumption about $g(\cdot)$
Dynamic exporting and investment decisions:
$\{e_{it}, d_{it} | z_{it}\}$ to estimate parameters of the model (sunk and fixed costs) using ML

Estimation

Set of parameters:

- Domestic Demand and Cost Parameters
  - $(\Phi^D, \beta_0, \beta_k)$: domestic revenue equation-recover unobserved productivity x_{it}.
  - productivity evolution equation $x_{it} = g(x_{it-1}, d_{it-1}, e_{it-1}) + \xi_{it}$

$$\begin{aligned} x_{it} &= \alpha_0 + \alpha_1 x_{it-1} + \alpha_2 (x_{it-1})^2 + \alpha_3 (x_{it-1})^3 \\ &\quad + \alpha_4 d_{it-1} + \alpha_5 e_{it-1} + \alpha_6 d_{it-1} e_{it-1} + \xi_{it} \end{aligned}$$

  - (η_X, η_D): total cost equation
- Dynamic Parameters
  - $(\rho_z, \sigma_\mu, \Phi^X)$: export revenue equation-only observed for exporters.
  - G^γ: firm's conditional choice probabilities

Estimation

Parameter	Discrete R&D	Continuous R&D
$1 + 1/\eta_D$	.8432 (.0195)*	.8432 (.0195)*
$1 + 1/\eta_X$	.8361 (.0164)*	.8361 (.0164)*
β_k	-.0633 (.0052)*	-.0636 (.0051)*
α_0	.0879 (.0198)*	.0866 (.0194)*
α_1	.5925 (.0519)*	.5982 (.0511)*
α_2	.3791 (.0915)*	.3777 (.0912)*
α_3	-.1439 (.0585)*	-.1592 (.0588)*
α_4	.0479 (.0099)*	.0067 (.0012)*
α_5	.0196 (.0046)*	.0197 (.0045)*
α_6	-.0118 (.0115)	-.0022 (.0014)
$SE(\xi_{it})$	.1100	.1098
sample size	3703	3703

Table 7 - Predicted Transition Rates for Continuing Plants - Model 2

Status year t		Status Year t+1			
		Neither	only R&D	only Export	Both
Neither	Predicted	0.866	0.019	0.110	0.008
	Actual	0.871	0.014	0.110	0.005
only R&D	Predicted	0.476	0.214	0.116	0.193
	Actual	0.372	0.336	0.058	0.233
only Export	Predicted	0.292	0.010	0.622	0.077
	Actual	0.213	0.010	0.708	0.070
Both	Predicted	0.049	0.028	0.138	0.784
	Actual	0.024	0.062	0.147	0.767

Data

Taiwanese Electronics Industry

• Balanced panel of 1,237 plants for 2000-2004

• Product classes: consumer electronics, telecommunication equipment, computers and storage equipment, electronics parts and components.

• Most dynamic industry in Taiwanese manufacturing sector

- Export participation .39 - compete with low-margins
- R&D performers .17 - major focus on process innovation
- Significant cross-sectional heterogeneity in productivity and activities.
- Sustained productivity growth, 3.6% annual in 80s and 90s.

Key variables: Revenue-domestic and export, Physical capital stocks (size), R&D expenditure, Variable costs-material, labor, energy

Data

• Transition pattern of R&D and exporting:

	Status Year t+1			
Status year t	Neither	only R&D	only Export	Both
All Firms	.563	.036	.255	.146
Neither	.871	.014	.110	.005
only R&D	.372	.336	.058	.233
only Export	.213	.010	.708	.070
Both	.024	.062	.147	.767

• Persistence in the status: (1) high sunk costs (2) high degree of persistence in the underlying profit heterogeneity.
• Exporting is more common than R&D investment.
• Undertaking one of the activities in year t→ more likely to add the other in year t + 1, less likely to drop the other in year t + 1

Estimation

Table 6 - R&D Investment Rates, Export Rates, and Productivity

	Year 2002	Year 2003	Year 2004
	Export Market Participation Rate		
Actual Data	0.395	0.392	0.390
Predicted	0.370	0.371	0.371
	R&D Investment Rate		
Actual Data	0.177	0.170	0.169
Predicted	0.172	0.168	0.167
	Average Productivity		
Actual Data	0.436	0.444	0.436
Predicted	0.449	0.441	0.432

Results

Productivity dynamics (estimation of $g(\cdot)$):

$$\frac{\delta\omega_{it} > 0}{\delta e_{it-1}} > 0; \frac{\delta\omega_{it}}{\delta_{it-1}} > 0; \frac{\delta^2\omega_{it}}{\delta e_{it}\delta d_{it}} < 0$$

Sunk and Fixed costs of Exporting and R&D:

- R&D costs roughly twice as big as Export costs
- Sunk costs are roughly twice as big as Fixed costs
- Around 10% of revenues

Interdependence between exporting and investment:

- Selection based on ω_{it} for both e_{it} and d_{it}
- A lot of persistence due to large sunk costs relative to fixed costs
- Probability of exporting decreasing in R&D and probability of investment decreases in export status due to the interaction in the productivity dynamics

Results

- Productivity in response to both R&D and exporting.
- Impact of R&D is larger.
- But, relatively low exporting cost makes it a more important channel.
- The interdependence of R&D and exporting is dominated by selection: stable export demand.