R&D Investment, Exporting, and Productivity Dynamics

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December 3, 2013

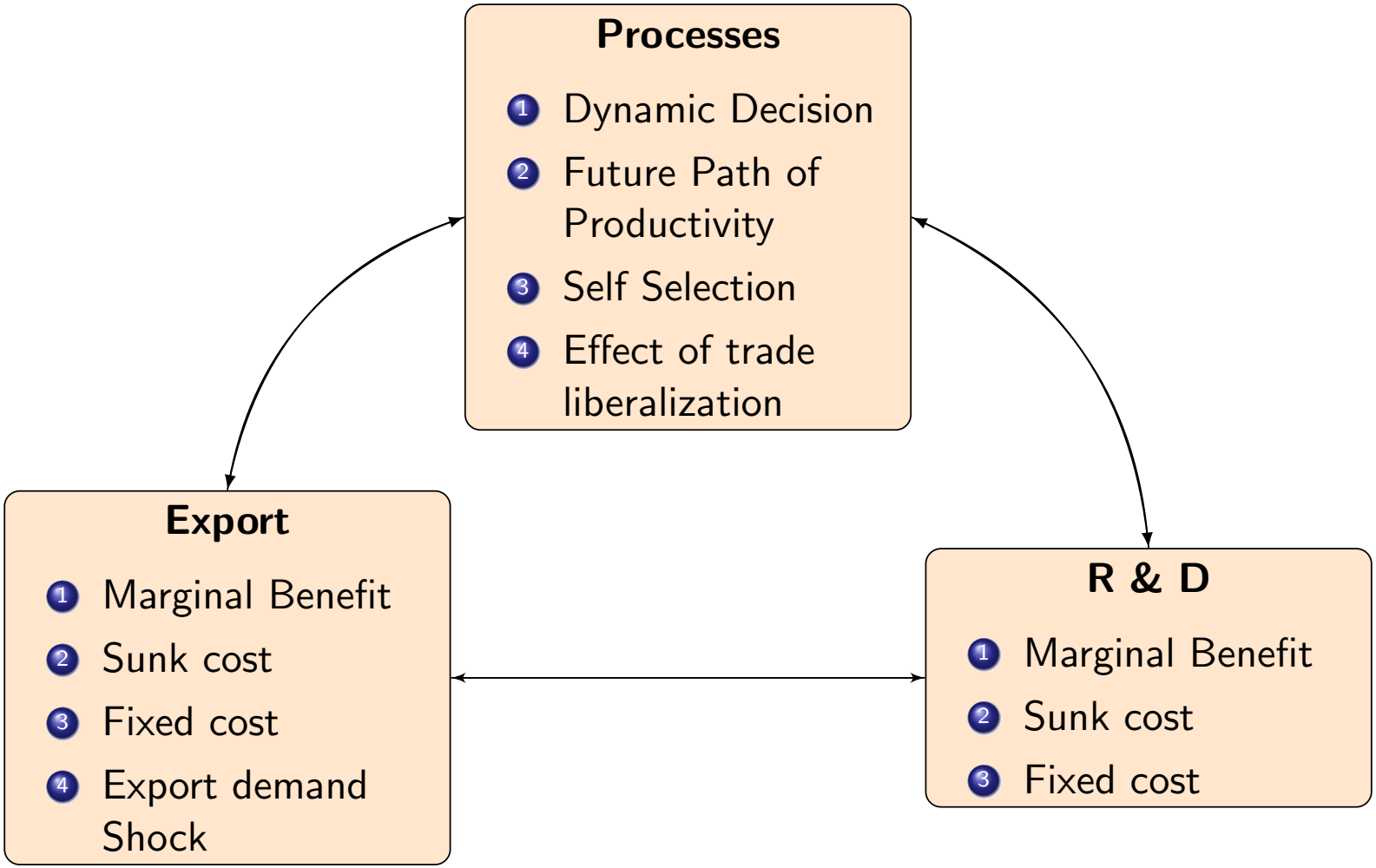
Firm's Decisions

(a) R& D

(b) Export

(c) Productivity

Firm's Decision



Research Questions

How past exporting and R&D affect productivity of the firm?

How post productivity of the firm affect's its decision to engage in exporting or conduct R&D? Whether these two decisions are interdependent?

How sunk cost and fixed cost of exporting are compared to each other? Are these costs heterogeneous?

How trade liberalization, reduction in trade cost or market export market expansion, affects probability of firm investment in R&D and export?

Overview

Data

- Taiwanese electronic industry for 2000-2004
- Observable: Export participation, discrete R&D investment, capital stock, domestic/export market revenue, Material and Energy expenditure
- Unobservable: Productivity, sunk and fixed cost of both R&D and Export, Export market Shock

Methodology

- Dynamic Structural Model (Choices affect path of productivity endogenously). Two stage process of estimation:
  - First Stage: Underlying process for producer productivity
  - Second Stage: Use results of first stage to estimate the dynamic decision of R&D, and export market participation: costs, marginal benefits
- Reduced Model

Overview

Results

- Both R&D and Export have a positive effect on the plan'ts future productivity
- Higher future productivity drives plants to self select into R&D and Export
- Expansion of the export market increase both Exporting and R&D investment
- Marginal benefit of both activities increase with plant's productivity
- Sunk cost of beginning either activity greater than the fixed cost of maintaining it
- Sunk & Fixed cost of investing in R&D are greater than sunk & Fixed cost of exporting
- Interdependence of both activities are not very important factor in the plant's decision
- Heterogeneity plays an important role in effect of productivity on investment in two activities

Marginal Cost and Demand Model

Model

$$ln(c_{it}) = lnc(k_{it}, w_t) - \omega_{it}$$
$$= \beta_0 + \beta_k lnk_{it} + \beta w_t - \omega_t$$

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

$$q_{it}^X = \frac{I_t^X}{P_t^X}(\frac{p_{it}^X}{P_t^X})^{\eta_X} e^{z_{it}} = \Phi_t^X(p_{it}^X)^{\eta_X} e^{z_{it}}$$

i: Plant or firm

t: Year index

c_{it}: Short run marginal cost

k_{it}: Firm's capital stock

w_t: Vector of variable input price common to all firms*

ω_{it}: Firm's productivity(unobs.)

q_{it}^D, q_{it}^X: Demand in domestic and export market

Q_t^D: Industry aggregate output

p_{it}^D, p_{it}^X: Price of firm(domestic/export)

P_t^D: Industry price index

I_t^D: Total market size

η_D, η_X: Constant elasticity of demand (domestic/export), common

Φ_t^D, Φ_t^X: Industry aggregates (market size and price)

z_{it}: Firm specific demand shifter (unobs.)

Assumptions

Structural Model of Exporting and R&D

- Processes: (1) Productivity evolution (2) The investment decisions
- Firms' heterogeneity: (1) productivity (2) Export demand curve
- Investments have feedback effect: path of future productivity
- Firm's decision consists of two components:
  - Static component: Productivity determines export short-run profits
  - Dynamic component: Make optimal R&D & exporting decisions
- Single output sold in both domestic and export market
- Sources heterogeneity (1) Capital stocks (obs.) (2) Productivity (unobs.)
- Marginal cost not vary with the output level: demand shocks not affect the static output decision
- Domestic and export markets: monopolistically competitive & segment from each other
- Demand curve in domestic & export market: Dixit-Stiglitz form

Firm's optimal revenue (F.O.C)

Model

$$lnr_{it}^{D} = (\eta_D + 1)ln(\frac{\eta_D}{\eta_D+1}) + ln\Phi_t^D + (\eta_D + 1)(\beta_0 + \beta_k lnk_{it} + \beta_w lnw_t - \omega_{it})$$

$$lnr_{it}^{X} = (\eta_X + 1)ln(\frac{\eta_X}{\eta_X+1}) + ln\Phi_t^X + (\eta_X + 1)(\beta_0 + \beta_k lnk_{it} + \beta_w lnw_t - \omega_{it}) + z_{it}$$

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

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

k_{it}: Firm's capital stock

w_t: Vector of variable input price common to all firms*

ω_{it}: Firm's productivity(unobs.)

η_D, η_X: Constant elasticity of demand (domestic/export), common

Φ_t^D, Φ_t^X: Industry aggregates (market size and price)

z_{it}: Firm specific demand shifter (unobs.)

π_{it}^D, π_{it}^X: Firm's short run profit in the domestic and export market: determines firm's decision to export and invest in R&D in the dynamic model

Assumptions

Firm's optimization problem

- Choose price in each market that maximizes the sum of domestic & export profits
- Capital stock of firm as fixed: short time series, so only additional complication
- Aggregate state variables $ln(\Phi^D)$ and $ln(\Phi^X_t)$ treated as exogenous first order Markov process (control for using time dummies)
- Firm's dynamic decision to export & invest in R&D
- Entering an export market or conducting R&D requires a non-recoverable sunk cost
- Productivity is endogenous: firm's exports and R&D

Transition of State Variables

Model

$$\omega_{it} = g(w_{it-1}, d_{it-1} + e_{it-1}) + \xi_{it}$$
$$= \alpha_0 + \alpha_1 w_{it-1} + \alpha_2 (w_{it-1})^2 + \alpha_3 (w_{it-1})^3$$
$$+\alpha_4 d_{it-1} + \alpha_5 e_{it-1} + \alpha_6 d_{it-1} e_{it-1} + \xi_{it}$$

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

$$s_{it} = (\omega_{it}, z_{it}, k_i, \Phi_t, e_{it-1}, d_{it-1})$$

d_{it-1}: Firm's R&D in the previous period

e_{it-1}: Firm's export market participation in previous period: Learning by exporting

ξ_i: Stochastic nature of productivity, iid shock$\sim (0, \sigma_\xi^2)$

ρ_z: First order autoregressive process serial correlation parameter

σ_μ: Standard deviation for the transitory shocks

s_{it}: State vector for firm i in year t

Assumptions

Decision making and Cost Assumptions

- Productivity evolves over time as a Markov process that depends on R&D, Export, Random Shock
- Exogenous randomness of productivity evolution, no correlation with R&D, Export and Productivity of previous moment (Strong!)
- Discrete decision of R&D and Export results in same level of increase in productivity (Strong!)
- Firm's export demand shock: First order Markov process, persistence
  - Nature of firm's product, set of countries they export, long term contractual or reputation
- Two stage decision of firm to Export and conduct R&D:
  - First stage: Firm observes values of fix and sunk cost of exporting then make discrete decision to export
  - Second Stage: Firm observes a fixed and sunk cost of investment and makes a discrete decision to undertake R&D
- Expenditures differ across firms b/c of difference in technological opportunities and expertise
- Four expenditures are i.i.d, since they don't know underlying technological opportunity (Strong!)

Dynamic Decisions: R&D and Exporting

Value Functions

$$V_{it}(s_{it}) = \int(\pi^D_{it} + max_{e_{it}}\{\pi^X_{it} - e_{it-1}\gamma^E_{it} - (1-e_{it-1})\gamma^S_{it} + v^E_{it}(s_{it}), v^D_{it}(s_{it})\})dG^\gamma$$

$$V^E_{it}(s_{it}) = \int(max_{d_{it}}\{\delta E_t V_{it+1}(s_{it+1}|e_{it}=1, , d_{it}=1) - d_{it-1}\gamma^I_{it} - (1-d_{it-1})\gamma^D_{it}, \delta E_t v_{it+1}(s_{it+1}|e_{it}=1, d_{it}=0)\})dG^\gamma$$

$$V^D_{it}(s_{it}) = \int(max_{d_{it}}\{\delta E_t V_{it+1}(s_{it+1}|e_{it}=0, d_{it}=1) - d_{it-1}\gamma^I_{it} - (1-d_{it-1})\gamma^D_{it}, \delta E_t v_{it+1}(s_{it+1}|e_{it}=0, d_{it}=0)\})dG^\gamma$$

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

$V_{it}(S_{it})$: Firm's value function before firm observes its fixed and sunk costs

γ^E_{it}: Fixed cost of exporting

γ^S_{it}: Sunk cost of export market entry

G^γ: Distribution of costs

$V^E_{it}(s_{it})$: Value of an exporting firm after it makes its optimal R&D decision

γ^I_{it}: Fixed cost of exporting

γ^D_{it}: Sunk cost of export market entry

$V^D_{it}(s_{it})$: Value of non exporting firm after it makes it's optimal R&D decision

$E_t V_{it}(s_{it}|e_{it}, d_{it})$: Expected value conditional on different choices for e_{it} and d_{it}

General Trade off

Decision to invest in exporting or R&D in year t when the current and expected gain exceeds the relevant fixed and sunk cost.

Dynamic Decisions: R&D and Exporting

Model

$$MBR_{it}(s_{it}|e_{it}) = E_t V_{it+1}(s_{it+1}|e_{it}, d_{it} = 1) - E_t V_{it+1}(s_{it+1}|e_{it} d_{it} = 0)$$

$$\Delta MBR_{it}(s_{it}) = MBR_{it}(s_{it}|e_{it} = 1) - MBR_{it}(s_{it}|e_{it} = 0)$$

$$MBE_{it}(s_{it}|d_{it}) = \pi^X_{it}(s_{it}) + V^E_{it}(s_{it}|d_{it-1}) - v^D_{it}(s_{it}|d_{it-1})$$

$$\Delta MBE_{it}(s_{it}) = MBE_{it}(s_{it}|d_{it} = 1) - MBE_{it}(s_{it}|d_{it} = 0)$$

$MBR_{it}(s_{it}|e_{it})$: Marginal benefit of R&D

$\Delta MBR_{it}(s_{it})$: Difference in future benefit of R&D b/w exporter and non exporter

$MBE_{it}(s_{it}|d_{it})$: Marginal benefit of exporting

$\Delta MBE_{it}(s_{it})$: Incremental impact of R&D on the return to exporting

Estimation: Two Stage Method

First Stage

- Parameters of the domestic revenue function
- Parameters of productivity evolution
- Joint estimation
- construct measure of firm productivity

Second Stage

- Dynamic discrete choice model of the export & R&D decision
- Estimate: Fixed and Sunk cost of Exporting and R&D
- Estimate: export revenue parameters
- Full set of parameters:
  $\eta_X, \eta_D, \Phi_t^X, \Phi_t^D, \beta_0, \beta_k, \beta_w, g(w_{it-1}, d_{it-1}, e_{it-1}), \sigma_\xi^2, G^\gamma, \rho_z, \sigma_\mu^2$
- $g(w_{it-1}, d_{it-1}, e_{it-1})$: function of productivity evolution.
- G^γ: Distribution of the fixed and sunk cost of exporting and R&D

First Stage

Model

$$lnr_{it}^{D} = (\eta_D + 1)ln(\frac{\eta_D}{\eta_D+1}) + ln\Phi_t^D + (\eta_D + 1)(\beta_0 + \beta_k lnk_{it} + \beta_w lnw_t - w_{it}) + u_{it}$$

$$\omega_{it}(k_{it}, m_{it}, n_{it})$$

$$lnr_{it}^{D} = \gamma_0 + \sum_{t=1}^{T} \gamma_t D_t + (\eta_D + 1)(\beta_k lnk_{it} - \omega_{it}) = \gamma_0 + \sum_{t=1}^{T} \gamma_t D_t + h(k_{it}, m_{it}, n_{it}) + \upsilon_{it}$$

$$\hat{\phi}_{it} = \beta_k^* lnk_{it} - \alpha_0^* + \alpha_1(\hat{\phi}_{it-1} - \beta_k^* lnk_{it-1}) + \alpha_2^*(\hat{\phi}_{it-1} - \beta_k^* lnk_{it-1})^2 + \alpha_3^*(\hat{\phi}_{it-1} - \beta_k^* lnk_{it-1})^3 - \alpha_r^* d_{it-1} - \alpha_5^* e_{it-1} - \alpha_6^* d_{it-1} e_{it-1} - \xi_{it}^*$$

u_{it}: Measurement error of revenue or optimization error in price choice. $(\eta_D+1)(-w_{it})+u_{it}$:Composite error term, contain firm productivity

m_{it}: Variable input levels for material(control)

n_{it}: Variable input levels for electricity(control)

γ_0: Combined demand elasticity terms into an intercept

D_t: The time varying aggregate demand shock and market-level factor prices (time Dummies)

$h(.)$: Cubic function of its argument

$\hat{\phi}_{it}$: Productivity series for each firm, Estimate of $(\eta_D+1)(\beta_k lnk_{it} - \omega_{it})$

$*$: means α, β_k is multiplied by (η_D+1): **Nonlinear Least Square**

First Stage

Model

$$\hat{\omega}_{it} = -\frac{1}{(\hat{\eta}_D+1)}\hat{\phi}_{it} + \hat{\beta}_k lnk_{it}$$

$$tvc_{it} = q_{it}^D c_{it} + q_{it}^X c_{it} = r_{it}^D(1+\frac{1}{\eta_D}) + r_{it}^X(1+\frac{1}{\eta_X}) + \epsilon_{it}$$

tvc_{it}: Sum of the product of output and marginal cost in each market*. F.O.C .Elasticity-weighted combination of total revenue in each market.

e_{it}: Measurement error in total cost.

Second Stage

Parameters to be Estimated

- Fixed and sunk cost of exporting and R&D
- Process for the export revenue shocks

Intuition

- Entry & Exit from the export market: information on distribution of sunk cost of entry γ_{it}^{S} and fixed cost γ_{it}^{E}
- The level of export revenue: information on the distribution of the demand shocks z_{it} conditional on exporting (infer unconditional shock)
- Discrete R&D choice: information on the distribution of fixed γ_{it}^{I} and sunk cost γ_{it}^{D} of R&D

Second Stage

Estimate Using

- Export market participation discrete decision
- R&D investment discrete decision
- Export revenue for the firms that choose to Export

Estimation

- Dynamic estimation based on the likelihood function for the observed pattern of:
  - Firm exporting: $e_i = (e_{i0}, \ldots, e_{iT})$
  - Exporting revenue $r_i^X = (r_{i0}^X, \ldots, r_{iT}^X)$
  - R&D discrete choice $d_i = (d_{i0}, \ldots, d_{iT})$
- Use unobserved firm level productivity series from first stage:
  - Productivity series: $\omega_i = (\omega_{i0}, \ldots, \omega_{iT})$

Second Stage

Model

$$P(e_i, d_i, r_i^X|\omega_i, k_i, \Phi) = P(e_i, d_i|\omega_i, k_i, \Phi, z_i^+)h(z_i^+)$$

$$P(e_{it} = 1|s_{it}) = P(e_{it-1}\gamma_{it}^F + (1 - e_{it-1})\gamma_{it}^S \leq \pi_{it}^X + V_{it}^E - V_{it}^D$$

$$P(d_{it} = 1|s_{it}) = P(d_{it-1}\gamma_{it}^I + (1 - d_{it-1})\gamma_{it}^D \leq \delta E_t V_{it+1}(s_{it+1}|e_{it}, d_{it} = 1)$$

$$-\delta E_t V_{it+1}(s_{it+1}|e_{it}, d_{it} = 0))$$

$P(.|.)$: Firm's contribution the likelihood function(joint dist of (e_i, d_i). **Simulated**

$h(.)$: Marginal distribution of z t **Assumption:** current period export status rather than lagged is relevant.

z_i^+: Time series of export market shocks. Given distribution **Simulated**.

$P(e_{it} = 1)$: Probability of exporting

$P(d_{it} = 1)$: Probability of investing in R&D

Estimation Method

Estimation Method

- Evaluate the likelihood function for each set of parameters rather than attempt to Maximum Likelihood
- Utilize a Bayesian Markov Chain Monte Carlo Estimator $\Theta = (\gamma^I, \gamma^D, \gamma^F, \gamma^S, \Phi^X, \rho_z, \sigma_\mu, \theta_0^e, \theta_0^d)$
- Objective function: characterize the posterior distribution of dynamic parameters (θ_0^e, θ_0^d) param of initial probit func
- **Assumption:** Each of the four costs drawn from separate independent exponential distribution
- Heterogeneity by allowing separate exponential distribution for large & small firm
- Firm's dynamic problem state vector: $s_{it} = (\omega_{it}, z_{it}, k_i, \Phi_t, e_{it-1}, d_{it-1})$
- Evaluate each plant's conditional choice probabilities: Export $p(e_{it}|s_{it})$ and R&D $p(d_{it}|s_{it})$

Estimation Procedure

Algorithm

- Begin with initial guess & Calculate $EV^0 = \int_{z'} \int_{\omega'} V^0(z', w', e, d, k, \Phi) dF(\omega'|\omega, e, d) dF(z'|z)$, from estimates of first step
- Calculate V_t^{E0} and V_t^{D0} using the following.
- Calculate value function $V^1(s)$ according to the following.
- Iterate across previous two steps until $|V^{j+1} - V^j| < \epsilon$
- Reduced model of 2007 paper had selection bias problem, and the problem is solved by endogenizing through structural model
- Since state space very large: use John Rust's discritization method for state space $N = 100$

Estimation Procedure

Algorithm

- Denote random grid points: $(\omega_1, z_1), \ldots, (\omega_n, z_n), \ldots (\omega_N, Z_N)$
- Solve dynamic problem and value function $\hat{V}$ on grid points by function iteration method
- Mean of costs are assumed to have prior distribution of $N(0, 1000)$
- Auto regression coefficient in export demand shock $U(-1, 1)$
- Separate probit equation for first year, initial point problem solution of Heckman

Estimation Procedure

Calculations

$$EV = \int_{z'} \int_{\omega'} V^0(z', \omega', e, d, k, \Phi) dF(\omega'|\omega, e, d)$$
$$dF(z'|z) = \frac{1}{N} \sum_{n=1}^{N} \hat{V}(z_n, \omega_n, e, d, k, \Phi) p^N(z_n, \omega_n|z, \omega, e, d)$$
$$p^N(z_n, \omega_n|z, \omega, e, d) = \frac{p(z_n|z)p(\omega_n|\omega,e,d)}{sum_{n=1}^{N} p(z_n|z)p(\omega_n|\omega,e,d)}$$

$$V^{E0}(d_{-1}) = P[\delta EV^0(1,1) - \delta EV^0(1,0) > d_{-1}\gamma^I + (1-d_{-1})\gamma^D].$$
$$(\delta EV^0(1,1) - d_{-1}E(\gamma^I|.) - (1-d_{-1})E(\gamma^D|.)) +$$
$$P[\delta EV^0(1,1) - \delta EV^0(1,0) \leq d_{-1}\gamma^I + (1-d_{-1})\gamma^D]\delta EV^0(1,0)$$

$$V^{D0}(d_{-1}) = P[\delta EV^0(0,1) - \delta EV^0(0,0) > d_{-1}\gamma^I + (1-d_{-1})\gamma^D].$$
$$(\delta EV^0(0,1) - d_{-1}E(\gamma^I|.) - (1-d_{-1})E(\gamma^D|.)) +$$
$$P[\delta EV^0(0,1) - \delta EV^0(0,0) \leq d_{-1}\gamma^I + (1-d_{-1})\gamma^D]\delta EV^0(0,0)$$

$$V^1(s) = \pi^D(\omega, k) +$$
$$P[\pi^X(z, \omega, k, \Phi), V^{E0}(d_{-1}) > e_{-1}\gamma^F + (1-e_{-1})\gamma^S].$$
$$(\pi^X(z, \omega, k, \Phi) + V^{E0}(d_{-1}) - e_{-1}E(\gamma^F|.) - (1-e_{-1})E(\gamma^S|.)) +$$
$$P[\pi^X(z, \omega, k, \Phi) + V^{E0}(d_{-1}) - V^{D0}(d_{-1}) \leq e_{-1}\gamma^F + (1-e_{-1})\gamma^S]V^{D0}(d_{-1})$$

Data: Annual Transition Rates for Continuing Plants

Status year t	Status year $t+1$			
	Neither	Only R&D	Only export	Both
All firms	0.563	0.036	0.255	0.146
Neither	0.871	0.014	0.110	0.005
Only R&D	0.372	0.336	0.058	0.233
Only export	0.213	0.010	0.708	0.070
Both	0.024	0.062	0.147	0.767

Demand, Cost and Productivity Evolution (1st Stage)

Parameter	Discrete R&D	Continuous R&D
$1+\frac{1}{\eta_D}$	0.843	0.843
	(0.019)*	(0.019)*
$1+\frac{1}{\eta_X}$	0.836	0.836
	(0.016)*	(0.016)*
log capital(β_k)	−0.063	−0.064
	(0.005)*	(0.005)*
Intercept of productivity (α_0)	0.088	0.087
	(0.020)*	(0.019)*
Lagged Productivity (α_1)	0.600	0.600
	(0.052)*	(0.051)*
Lagged Productivity (α_2)	0.380	0.378
	(0.091)*	(0.091)*
Lagged Productivity (α_3)	−0.144	−0.159
	(0.058)*	(0.059)*
Lagged R&D(α_4)	0.048	0.007
	(0.010)*	(0.001)*
Lagged Export (α_5)	0.020	0.020
	(0.005)*	(0.005)*
Interaction (α_6)	−0.12	−0.002
	(0.011)	(0.001)
SE (ξ_{it})	0.110	0.110
Sample Size	3,703	3,703

Reduced form participation and export revenue

Dependent variable	Productivity (ω_{it})	Capital (k_{it})	Lg Export (e_{it-1})	Lg R&D(d_{it-1})	Other
Bivariate probit on exporting and R&D					
Exporting (e_{it})	1.63 (0.16)*	0.06 (0.02)*	1.80 (0.06)*	0.19 (0.08)*	
R&D (d_{it})	1.65 (0.23)*	0.20 (0.03)*	0.34(0.08)*	1.86(0.08)*	$\rho = 0.17$
Export Revenue					
Log Revenue (lnr_{it}^{X})	6.45 (0.17)*	0.41 (0.02)*			
Export Revenue with Fixed Effect (z_i)					
Log Revenue (lnr_{it}^{X})	5.55 (0.31)*	0.43 (0.10)*			$Var(z) = 0.72$

Dynamic Parameter Estimates

Means and standard deviations of the posterior distribution					
Model 1 (Same cost distribution)			Model 2 (Heterogeneity in cost distribution)		
Parameter	Mean	Standard Deviation	Parameter	Mean	Standard Deviation
R&D Fixed Cost (γ^I)	67.60	3.93	Small(γ_1^I)	46.26	7.04
			Large(γ_2^I)	66.60	3.42
R&D Sunk Cost (γ^D)	354.28	31.38	Small(γ_1^D)	381.91	66.52
			Large(γ_2^D)	388.71	41.96
Export Fixed Cost (γ^F)	11.07	0.39	Small(γ_1^F)	5.73	0.30
			Large(γ_2^F)	15.96	0.70
Export Sunk Cost (γ^S)	50.75	3.48	Small(γ_1^S)	51.85	6.04
			Large($\gamma_2 F^S$)	67.40	6.70
Export rev intercept (Φ^X)	3.81	0.06	Φ^X	3.87	0.06
Export rev AR process (ρ^X)	0.77	0.01	ρ_z	0.76	0.01
Export rev STD (σ_μ)	-0.29	0.02	σ_μ	-0.29	0.02

In Sample Model Performance

	2002	2003	2004
Export Market Participation Rate			
Actual data	0.39	0.39	0.39
Predicted	0.37	0.37	0.37
R&D investment rate			
Actual data	0.18	0.17	0.17
Predicted	0.17	0.17	0.17
Average Productivity			
Actual data	0.44	0.44	0.44
Predicted	0.45	0.44	0.43

Status year t		Status year $t+1$			
		Neither	Only R&D	Only export	Both
Neither	Predicted	0.87	0.02	0.11	0.01
	Actual	0.87	0.1	0.11	0.00
Only R&D	Predicted	0.48	0.21	0.12	0.19
	Actual	0.37	0.34	0.06	0.23
Only export	Predicted	0.29	0.01	0.62	0.08
	Actual	0.21	0.01	0.71	0.07
Both	Predicted	0.05	0.03	0.14	0.78
	Actual	0.2	0.6	0.15	0.77

Marginal Benefit of Exporting (Millions of NT dollars)

	V_t^E		V_t^D		$MBE = \pi_t^X + V_t^E - V_t^D$	
ω_t	$d_{t-1} = 1$	$d_{t-1} = 0$	$d_{t-1} = 1$	$d_{t-1} = 0$	$d_{t-1} = 1$	$d_{t-1} = 0$
-0.19	132.5	132.4	130.9	130.7	2.1	2.1
-0.02	138.9	138.5	136.3	135.9	3.7	3.8
0.15	151.8	150.9	147.3	146.3	7.1	7.2
0.32	179.4	176.3	170.9	167.4	14.7	15.2
0.49	245.3	235.6	228.9	217.7	31.3	32.9
0.67	392.6	365.3	362.9	331.9	65.3	69.1
0.84	714.0	655.9	667.0	599.1	132.3	142.1
1.01	1,206.3	1,117.4	1,143.7	1,041.5	266.8	280.1
1.18	1,911.3	1,790.0	1,834.0	1,695.3	565.7	583.2
1.35	2,689.1	2,568.8	2,610.8	2,471.7	1,246.9	1,265.7

Costs of Exporting and R&D (millions of NT dollars)

	Mean Export Costs among exporters ($d_{t-1} = 1$)		Mean R&D costs among investors ($e_t = 1$)	
ω_t	Fixed cost	Sunk cost	Fixed cost	Sunk cost
-0.19	0.97	1.04	1.32	1.34
-0.02	1.61	1.80	2.06	2.12
0.15	2.64	3.33	3.41	3.59
0.32	4.18	6.50	6.55	7.28
0.49	6.21	12.32	12.83	15.64
0.67	8.50	21.06	24.01	33.74
0.84	9.86	30.72	36.28	60.78
1.01	10.35	37.17	43.49	86.61
1.18	10.67	43.54	49.35	113.93
1.35	10.70	47.02	48.26	114.87

Counterfactual: Plant Response to Exogenous Increase in Export Market Size

	Year			
	2	5	10	15
Endogenous productivity $\omega_{it} = g(\omega_{it-1}, d_{it-1}, e_{it-1}) + \xi_{it}$				
Change in proportion of exporters	5.2	9.0	10.0	10.2
Change in the proportion of R&D performers	2.5	3.5	4.1	4.7
Percentage change in mean productivity	0.5	1.5	3.7	5.3
Endogenous productivity: $\omega_{it} = g(\omega_{it-1}, d_{it-1}) + \xi_{it}$				
Change in proportion of exporters	2.0	3.9	4.0	4.4
Change in proportion of R&D performers	1.8	2.6	3.5	4.0
Percentage change in mean productivity	0.0	0.8	1.9	2.9
Endogenous productivity: $\omega it = g(\omega_{it-1}, e_{it-1}) + \xi_{it}$				
Change in proportion of exporters	3.4	5.9	7.2	7.6
Percentage change in mean productivity	0.0	0.0	1.2	1.8
Exogenous productivity: $\omega it = g(\omega_{it-1}) + \xi_{it}$				
Change in proportion of exporters	4.6	5.7	5.8	5.5

Finding's Summary and Conclusion

Both R&D and Export have a positive effect on the plan'ts future productivity

Higher future productivity drives plants to self select into R&D and Export

Expansion of the export market increase both Exporting and R&D investment

Marginal benefit of both activities increase with plant's productivity

Finding's Summary and Conclusion

Sunk cost of beginning either activity greater than the fixed cost of maintaining it

Sunk & Fixed cost of investing in R&D are greater than sunk & Fixed cost of exporting

Interdependence of both activities are not very important factor in the plant's decision

Heterogeneity plays an important role in effect of productivity on investment in two activities

Thank You