Lecture Notes on Productivity III: R&D, Export, and Technology Adoption

April 2009

Costantini and Melitz 2007

complicated relationship between export and productivity

- selection: more productive firms self-select into export market
- learning by exporting: mixed empirical evidence
- potential channel to reconcile these features: firms jointly make innovation and export market participation decisions.
- based on Melitz (2003), Hopenhayn (2002), and innovation option.

demand and innovation

- continuum of varieties $\omega \in \Omega$. Let $P_t = [\int_\omega p_t(\omega)^{1-\sigma}]^{1/(1-\sigma)}$.
- Demand for individual variety ω is $q_t(\omega) = AP_t^{\sigma-\eta} p_t(\omega)^{-\sigma}$
- with costant marginal cost $1/\nu$ and fixed cost F, profit-maximization gives

$$\pi_t^D(\nu) = \frac{(\sigma-1)^{\sigma-1}}{\sigma^\sigma} AP_t^{\sigma-\eta} \nu^{\sigma-1} - F$$

- one-time opportunity to upgrade from A to B. Need to pay i.i.d. innovation cost S^B.

trade and firm decisions

- exporters incur per-unit trade costs τ_t, per period fixed cost F^X and sunk cost S^X. Thus

$$\pi_t^X(\nu) = \frac{(\sigma-1)^{\sigma-1}}{\sigma^\sigma} A P_t^{\sigma-\eta} (\frac{\nu}{\tau_t})^{\sigma-1} - F^X$$

- Possible states in addition to ν: (AD, BD, AX, BX), thus $V_t(v,z) = max[0, V_t^C(v,z)]$.
- The value of continuation

$$V_t^C(v,z) = max_{z'}\{\pi_t(v,z') - S^B I^B(z,z') - S^X I^X(z,z') + \beta(1-\delta)\int_v V_{t+1}(v',z') dG[v'|v, I^B(z,z')]\}$$

- Note that $E(v'|v,0) = v$

decisions

- exit segment always encompass the lowest productivity levels to a cutoff
- among both A and B, more productive firms choose to export, more productive firms choose to innovate too.
- some ranking of transition vary with the level of trade costs: AD to BD or AD to AX first?
- finally, $V_t^E = \int V_t(v, AD)dG_E(v) - S$ determines entry.

equilibrium is characterized by a time path for the price index P_t, the measure of firms in each state μ_{zt}, and the mass of entrants M_{Et} that satisfies firm value maximization, free entry, and aggregate industry accounting.

Table 5: Distribution of Firms and Transitions Across States

Stationary States	# firms	Firm Distribution AD	BD	AX	BX	Transitions ADBD	ADAX	ADBX	BDBX	AXBX
Pre	570	77%	8%	0%	15%	4%	0%	0%	5%	0%
Post	446	51%	4%	3%	42%	0%	9%	2%	2%	6%

UA year	# firms	Firm Distribution AD	BD	AX	BX	Transitions ADBD	ADAX	ADBX	BDBX	AXBX
0	570	77%	8%	0%	15%	4%	0%	0%	5%	0%
1	570	77%	8%	0%	15%	4%	0%	0%	5%	0%
2	570	77%	8%	0%	15%	4%	0%	0%	5%	0%
3	570	77%	8%	0%	15%	4%	0%	0%	5%	0%
4	473	59%	2%	4%	35%	0%	16%	6%	8%	10%
5	441	55%	2%	3%	40%	0%	10%	2%	1%	7%
6	438	53%	2%	3%	42%	0%	9%	2%	1%	6%
7	439	52%	3%	3%	42%	0%	9%	2%	1%	6%
8	440	52%	3%	3%	42%	0%	9%	2%	1%	6%

AA year	# firms	Firm Distribution AD	BD	AX	BX	Transitions ADBD	ADAX	ADBX	BDBX	AXBX
0	570	77%	8%	0%	15%	4%	0%	0%	5%	0%
1	619	79%	8%	0%	13%	3%	0%	0%	4%	0%
2	628	78%	9%	0%	13%	4%	0%	0%	5%	0%
3	597	75%	10%	0%	15%	9%	0%	0%	8%	0%
4	461	57%	2%	3%	39%	0%	11%	4%	14%	6%
5	412	50%	2%	3%	45%	0%	10%	2%	1%	6%
6	421	51%	2%	3%	44%	0%	9%	2%	1%	6%
7	428	51%	3%	3%	43%	0%	9%	2%	1%	6%
8	433	51%	3%	3%	43%	0%	9%	2%	1%	6%

Das Roberts Tybout, Econometrica 2007

motivations of modeling export dynamics with firm heterogeneity

- seemingly similar stimuli have given rise to different export responses
- export dynamics: joint forces of market conditions, entry costs, distribution of export payoff
- entry margin v.s. intensive margin

key assumptions

- monopolistically competitive markets
- marginal costs do not respond to output shocks, shocks shift domestic schedule not affect optimal level of exports
- heterogeneity in marginal costs and foreign demand schedules

gross export profits and revenues

- export revenue function

$$lnR_{it}^{f*} = ln\eta_i + \psi_0 z_i + \psi_1 e_i + v_{it}$$

profit $\pi_{it}^{*} = R_{it}^{f*} - C_{it}^{f*} = \eta_i^{-1} R_{it}^{f*}$

- identify firm-specific mark-up

$$C_{it} = C_{it}^{f} + C_{it}^{d} = R_{it}^{f}(1 - \eta_i^{-1}) + R_{it}^{f}(1 - \eta_i^{-1}(1 + \nu))$$

- exchange rate e follows a narmal AR(1) process, where $v_{it} = \iota' x_{it}$, where $x_{it} = (x_{1it}, x_{2it}, ...x_{mit})$, so v_{it} has a stationary ARMA(m,m-1) representation.

export market participation

- fixed costs of exporting $\gamma_F - \epsilon_{1it}$, start-up costs $\gamma_S z_i + \epsilon_{1it} - \epsilon_{2it}$, ϵs are serially uncorrelated.
- Net current export profit for firm i

$$\begin{aligned} u(.) &= \pi^* - \gamma_F + \epsilon_{1it}, y_{it} = 1, y_{it-1} = 1 \\ &= \pi^* - \gamma_F - \gamma_S z_i + \epsilon_{2it}, y_{it} = 1, y_{it-1} = 0 \\ &= 0, y_{it} = 0 \end{aligned}$$

- The bellman equation is:

$$\begin{aligned} V_{it} &= max_{y_{it}}[u(e_t, x_{it}, z_i, \epsilon_{it}, y_{it}, y_{it-1}) + \delta E_t V_{it+1}] \\ E_t V_{it+1} &= \int_{e'} \int_{x'} \int_{\epsilon'} V_{it+1} f_e(e'|e_t) f_x(x'|x_{it}) f_\epsilon(\epsilon'|\epsilon) d\epsilon' dx' de' \end{aligned}$$

- The decision rule is $y_{it} = I(u(.) + \delta \Delta E_t V_{it+1}(e_t, x_{it}, z_i) > 0)$

estimation

- Data:$D_i = (y_{i0}^T, R_{i0}^{fT}, R_{i0}^{dT}, C_{i0}^T, e_0^T, z_i)$.
- Three difficulties: unobserved serially correlated errors x_{it}s, endogenous initial condition y_{i0}, and incidental parameters η_i.
- The shocks x_{it}s are censored. Make use of the fact that there exits functions $x_{is}^t = x_s^t(v_i^+, \mu_i)$, where $v_i^+ = \{lnR_{it}^f - ln\eta_i - \psi_0 z_i - \psi_1 e_t; R_{it}^f > 0\}$ is the set of censored v_{it}s (assume it is q_i dimensional), and μ_i is a vector of mT i.i.d standard normal variates.
- Thus we could write the *ith* plant contribution to likelihood

$$P[y_{i0}^T, R_{i0}^{fT} | e_0^T, z_i] = P[y_{i0}^T | v_i^+, e_0^T, z_i] h(v_i^+)$$
$$= [\int_{\mu_i} P[y_{i0}^T | e_0^T, x_0^T(v_i^+, \mu_i), z_i] g(\mu_i) d\mu_i] h(v_i^+)$$

- Initial condition problem:

$$P[y_{i0}^T | e_0^T, x_0^T(v_i^+, \mu_i), z_i] =$$
$$P[y_{i1}^T | e_1^T, x_1^T(v_i^+, \mu_i), z_i, y_{i0}] P[y_{i0}^T | e_0, x_0(v_i^+, \mu_i), z_i]$$

- Use a Heckman (1981) method to express the prob of exporting in initial year as a reduced-form probit.
- Finally, use the solved optimal policy and use the fact i.i.d. ϵ

$$P[y_{i1}^T | e_1^T, x_1^T(v_i^+, \mu_i), z_i, y_{i0}] =$$
$$\Pi_{t=1}^T (E_{\epsilon_{it}} I(y_{it}^* > 0 | e_t, x_t(v_i^+, \mu_i), z_i, \epsilon_{it}, y_{it-1})^{y_{it}})$$
$$(E_{\epsilon_{it}} I(y_{it}^* \leq 0 | e_t, x_t(v_i^+, \mu_i), z_i, \epsilon_{it}, y_{it-1})^{1-y_{it}})$$

Schimidt-Dengler 2006

- A timeing game of new technology adoption
- A panel of US hospitals
  - different in market structure and demand
  - variation in adoption times of MRI
- How much does competition account for the incentive of adoption? Business stealing effect is substantial

- I firms in the market, time is discrete, firm's action every period $a_i^t \in (0, 1)$: adopt or not.
- Firm's history of actions h_t^i: t by 1 vector containing zeros until i has adopted and ones from then on. H^t is the set of all possible histories at t.
- Pure adoption strategy $s_t^i : h_t \longrightarrow A_t^i(h_t)$, any $h_t \in H_t$. Note that action set A_t^i depends on h_t. (If has adopted, only 1).
- Number of adopters in period t: $n_t = \sum_{i=1}^{I} a_t^i$
- Intertemporal profits are:

$$\Pi^i = \sum_{t=1}^{t^i-1} \beta^t \pi_0^i(n_t) + \sum_{t=t^i}^{\infty} \beta^t \pi_1^i(n_t) - \beta^{t^i} C(t^i)$$

- payoff-key assumptions
  - decreasing returns: $\pi_1^i(n-1) - \pi_0^i(n-2) \geq \pi_1^i(n) - \pi_0^i(n-1)$, any i and n. More firms adopted, less gain.
  - profitability order invariant: $\pi_1^i(n) - \pi_0^i(n-1) > \pi_1^j(n) - \pi_0^j(n-1)$ iff $\pi_1^i(m) - \pi_0^i(m-1) > \pi_1^j(m) - \pi_0^j(m-1)$, for any firm i, j and market structure m, n.
- payoff-key assumptions: decreasing and convex in time. It falls eventually to a level such that all firms adopt.
- equilibrium selection: focus on **sequential moves** each period t. Firm with the ith largest marginal benefit to adopt $\pi_1^i(n) - \pi_0^i(n-1)$ move ith.

- Assumption of sequential moves insures a unique SPNE of complete information. (Similar to Berry 92).
- A simple recursive algorithm for history of equilibrium play
    - order firms in profitability: firm i is the ith most profitable
    - Let $\bar{t}$: time by which all firms adopt.
    - $\bar{t}$-1:firm I decide whether to adopt, regardless of history of play.
    - Calculate value of each history **before** firm I makes decision: solve firm $I-1$'s adoption decision.
    - repeat backwards until period $t=1$.
- stand alone incentive vs preemption incentive.

- given n as the number of firms have adopted

$$\pi_0^i(n,\theta) = \alpha_0 + Z\gamma_0 + W_i\mu_0 + \delta_0 log(n+1)$$
$$\pi_1^i(n,\theta) = \alpha_1 + Z\gamma_1 + W_i\mu_1 + \delta_1 log(n) + \epsilon_i$$
$$C(t^i) = c\lambda^{t^i}$$

- ϵ_i is a combination of both firm and market specific, iid normal:

$$\epsilon^i = exp(\sqrt{(1-\rho^2)}\nu^i + \rho\nu^l$$

- both firm heterogeneity $\mu_1 - \mu_0, \epsilon^i$ and competition $\delta_1 - \delta_0$ will cause diffusion.

Table 1: Comparison of Sample Markets to all US markets

	Sample	US		Sample	US
Total # of			% of Hospitals		
HCSA's	306	802	w/ Residency training	2.44%	19.01%
Hospitals	780	5,094	Private nonprofit	52.05%	60.22%
Average			Government	41.41%	25.17%
Bed Capacity	99	195	For-profit	6.54%	14.60%
Population	72,737	473,895	System member	23.97%	39.92%
Per Capita Income	16,600	18,083	w/ MRI	23.33%	33.63%

Table 2: Hospital & Market Characteristics by # of hospitals in a market

	# of Hospitals				
	1	2	3	4	Total
Average					
Bed capacity	80	95	102	108	99
Population	24,089	55,668	89,563	114,680	72,737
Per Capita Income	16,701	16,623	16,548	16,550	16,600
Adoption rate	22.4%	19.2%	21.9%	27.5%	23.3%
% of Markets					
w/ 1 MRI	22.6%	27.5%	36.4%	33.3%	30.4%
w/ 2 MRI		5.5%	14.8%	20.3%	10.5%
w/ 3 MRI			0.0%	10.2%	2.3%
w/ 4 MRI				1.4%	0.3%
# number of markets	58	91	88	69	306

Table 3: Parameter Estimates

θ	(1)	(2)	(3)	(4)	(5)
$\alpha_1 - \alpha_0$	11.3400	10.6630	10.5740	10.6997	10.8841
	(0.3944)	(1.2531)	(0.9752)	(0.4389)	(3.1087)
δ_1	-4.425	-4.267	-3.467	-3.0698	-2.9559
	(-0.2205)	(-0.8443)	(-0.8128)	(0.2833)	(0.4694)
δ_0	-0.8057	-0.7782	-0.8475	-0.8061	-0.8104
	(0.0311)	(0.1348)	(0.2093)	(0.0602)	(0.2211)
c	410.82	456.96	468.54	467.0345	439.7912
	(7.1357)	(4.9101)	(6.5589)	(9.4283)	(35.3069)
$1/\lambda - 1$	0.0344	0.0368	0.0311	0.0341	0.0372
	(0.0018)	(0.0016)	(0.0088)	(0.0018)	(0.0040)
$(\gamma_1 - \gamma_0)_{Pop}$	0.9442	0.6599	0.895	0.8994	0.7299
	(0.0232)	(0.0370)	(0.1706)	(0.0462)	(0.1207)
$(\gamma_1 - \gamma_0)_{PCI}$	0.0007	0.1923	0.1034	0.0069	0.0009
	(0.0021)	(0.0425)	(0.0366)	(0.0124)	(0.0067)
$(\mu_1 - \mu_0)_{beds}$		0.9218	0.8369	0.8327	0.9186
		(0.0827)	(0.1659)	(0.0547)	(0.1491)
$(\mu_1 - \mu_0)_{NP}$		1.6644	1.6018	1.2925	1.2909
		(0.4895)	(0.3995)	(0.3239)	(0.2374)
$(\mu_1 - \mu_0)_{FP}$		1.3652	0.8813	1.2816	1.2060
		(2.3266)	(0.3521)	(0.1724)	(0.5822)
ρ			0.5756	0.2381	0.1946
			(0.0613)	(0.2381)	(0.1056)

Note: Standard errors are in parentheses. Number of simulations is 20.

Table 4: Regulatory Regime versus Subgame Perfect Equilibrium

	# of Hospitals					
	2		3		4	
	$\mathbf{T}^R - \mathbf{T}^*$	$se(\Delta\mathbf{T})$	$\mathbf{T}^R - \mathbf{T}^*$	$se(\mathbf{\Delta T})$	$\mathbf{T}^R - \mathbf{T}^*$	$se(\mathbf{\Delta T})$
1^{st}	1.2747	(0.0964)	2.0341	(0.1204)	2.5942	(0.1174)
2^{nd}	3.3956	(0.0539)	3.9205	(0.0651)	4.3043	(0.0975)
3^{rd}			4.2159	(0.0522)	4.4493	(0.0787)
4^{th}					4.6667	(0.0674)
Mean	2.3352	(0.0552)	3.3902	(0.0483)	4.0036	(0.0627)
ΔV	1.86%	(0.09)	3.86%	(0.15)	5.56%	(0.21)

Notes: T^*: Adoption time in subgame perfect equilibrium

T^R: Adoption time maximizing industry profits

ΔV: change in industry profits when moving regulatory regime

Standard errors are in parentheses.

Table 5: Nash Equilibrium versus Subgame Perfect Equilibrium

	# of Hospitals					
	2		3		4	
	$\mathbf{T}^{NE} - \mathbf{T}^*$	$se(\Delta\mathbf{T})$	$\mathbf{T}^{NE} - \mathbf{T}^*$	$se(\mathbf{\Delta T})$	$\mathbf{T}^{NE} - \mathbf{T}^*$	$se(\mathbf{\Delta T})$
1^{st}	0.4725	(0.0846)	0.7613	(0.1047)	0.5362	(0.0890)
2^{nd}			0.2046	(0.0462)	0.3768	(0.0656)
3^{rd}					0.1159	(0.0388)
4^{th}						
Mean	0.4725	(0.0846)	0.4830	(0.0557)	0.3430	(0.0424)
ΔV	0.33%	(0.07)	0.84%	(0.10)	0.91%	(0.12)

Notes: T^*: Adoption time in subgame perfect equilibrium

T^{NE}: Adoption time in Nash equilibrium

ΔV: change in industry profits when moving to Nash equilibrium

Standard errors are in parentheses.