Dynamic Impact of Exporting on Firm R&D Investment

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Firm Innovation and Exporting - Empirical Evidence

- In firm data - positive cross-section correlation between exporting and measures of innovation (R&D, investment in new products, patents, worker training)
- Direction of causation is less clear, potentially complex
  - R&D investment $\rightarrow$ higher productivity/profits $\rightarrow$ ability to compete in export markets
    - Large empirical literatures establishing each linkage
  - Exporting $\rightarrow$ direct productivity improvements / knowledge spillovers / sales in a larger market $\rightarrow$ raise the return to R&D
    - Empirical studies rely on export market shocks (trade liberalization) to estimate causal impacts on innovation
    - Structural model of firm's choice of R&D - pathways linking R&D and exporting

Dynamic Model of R&D Investment

- Empirical model of the firm's decision rule for R&D investment
  - R&D improves the *path* of future productivity, sales, profits, and firm value
  - Increase in long-run firm value measures the expected benefit of R&D
  - Firm chooses R&D to set expected benefit equal to the cost of productivity improvement
- Mechanism can differ for domestic/exporting firms
  - R&D can have different productivity effects in each market.
  - Productivity paths can affect sales/profits differently in each market
  - Creates different incentives to invest in R&D between exporting/domestic firms
- Counterfactuals - study impact on R&D investment
  - Export market expansion/tariffs
  - R&D subsidies

Swedish Firm-Level Data

- Combination of Community Innovation Survey, R&D Survey, Industrial Census data sources
  - Annual data 2003-2010
  - Six high-tech manufacturing industries and six low-tech
  - Sample of 3374 observations in HT and 1834 in LT industries.
- Key variables:
  - Innovation expenditure: R&D spending and licensing
  - Export sales and domestic market sales
  - Input - capital stock, labor, materials (to measure productivity)

Relationship Between Export and R&D Intensity

Table 3: R&D Investment by Export Category

	Pr(R&D>0)	Percentiles for R&D Intensity		
		P(10)	P(50)	P(90)
High-Tech Industries				
No Exports	0.175	0.002	0.015	0.138
Export Intensity ≤P(25)	0.393	0.002	0.017	0.144
P(25)<Export Intensity≤P(50)	0.582	0.003	0.019	0.111
Export Intensity>P(50)	0.776	0.004	0.033	0.143
Low-Tech Industries				
No Exports	0.162	0.001	0.009	0.090
Export Intensity≤P(25)	0.259	0.001	0.008	0.069
P(25)<Export Intensity≤P(50)	0.292	0.001	0.007	0.041
Export Intensity>P(50)	0.464	0.001	0.010	0.047

- Exports and R&D are positively correlated on extensive and intensive margin in both industries
- Less overall R&D investment in low-tech industries

Model - Profit Function and Productivity Evolution

- Estimate short-run profit functions for domestic and export market sales to uncover domestic (ω_{jt}) and export market (μ_{jt}) productivities.
  - Domestic Firm:
$$\pi_{jt}^{d} = -\frac{1}{\eta_d} R_{jt}^{d}(\Phi_t^d, k_{jt}, \omega_{jt})$$
  - Exporting Firm:
$$\pi_{jt}^{x} = -\frac{1}{\eta_d} R_{jt}^{d}(\Phi_t^d, k_{jt}, \omega_{jt}) - \frac{1}{\eta_f} R_{jt}^{f}(\Phi_t^f, k_{jt}, \mu_{jt})$$
- The two productivities evolve endogenously in response to R&D investment (rd):

$$\begin{aligned} \omega_{jt+1} &= g_\omega(\omega_{jt}, rd_{jt}) + \varepsilon_{jt+1} \\ \mu_{jt+1} &= g_\mu(\mu_{jt}, rd_{jt}) + \nu_{jt+1} \end{aligned}$$

$g_\omega(\omega_{jt}, rd_{jt})$ and $g_\mu(\mu_{jt}, rd_{jt})$ are quadratic functions.

Productivity Evolution

Parameter Estimates for Productivity Evolution		
Variable	Domestic Revenue	Export Revenue
High- Tech Industries		
ω_{t-1} or μ_{t-1}	0.994 (0.030)	0.997 (0.021)
ω^2_{t-1} or μ_{t-1}	-0.031 (0.001)	-0.022 (0.000)
$ln(rd_{t-1})$	0.017 (0.002)	0.023 (0.003)
$ln(rd_{t-1})^2$	-0.001 (2.4E-5)	-0.002 (2.6E-5)
$ln(rd_{t-1})\omega_{t-1}$	0.006 (7.0E-5)	0.006 (6.E-5)
Low-Tech Industries		
ω_{t-1} or μ_{t-1}	1.038 (0.006)	0.979 (0.001)
ω^2_{t-1} or μ_{t-1}	-0.032 (0.003)	-0.001 (6.1E-5)
$ln(rd_{t-1})$	0.005 (0.001)	0.010 (6.1E-5)
$ln(rd_{t-1})^2$	-0.001 (2.4E-5)	-0.000 (4.3E-5)
$ln(rd_{t-1})\omega_{t-1}$	0.003 (0.000)	0.001 (0.000)

- Productivity is highly persistent $\Longrightarrow$ R&D impacts depreciate slowly.
- R&D spending has a larger, positive impact in export market.
- R&D spending has a larger, positive impact in high-tech industries.

Model - Dynamic Choice of R&D

- Firm's value function with state $s_{jt} = (k_{jt}, \omega_{jt}, \mu_{jt})$:

$$\begin{aligned} V(s_{jt}) &= \pi(s_{jt}) + \max\{E_t V(s_{jt+1}|s_{jt}, rd_{jt} = 0), \\ &\quad \max_{rd>0} \left[E_t V(s_{jt+1}|s_{jt}, rd_{jt}) - C_I(rd_{jt}, \upsilon_{jt}, I(rd_{jt-1}))\right]\} \end{aligned}$$

Expected future firm value conditional on R&D choice:

$$E_t V(s_{jt+1}) = \beta \int_\xi \int_\nu V(k, g^\omega(\omega, rd, \xi), g^\mu(\mu, rd, \nu)) d\xi d\nu$$

Innovation cost function:

$$C_I(rd_{jt}, \upsilon_{jt}, I(rd_{jt-1})) = VC(rd_{jt}, \upsilon_{jt}) + FC(I(rd_{jt-1})).$$

$$VC(rd_{jt}, \upsilon^*_{jt}) = \theta_1 rd_{jt} + \theta_2 rd^2_{jt} + \sigma_\upsilon rd_{jt} \upsilon_{jt}$$

Expected Benefit of R&D

- The **expected benefit of investing in R&D** is

$$\Delta EV(s_{jt}) = E_t V(s_{jt+1}|s_{jt}, rd_{jt}) - E_t V(s_{jt+1}|s_{jt}, rd_{jt} = 0)$$

- Extensive margin: Firm chooses $rd > 0$ if:

$$\Delta EV(s_{jt}) \geq C_I(rd_{jt}, \upsilon_{jt}, I(rd_{jt-1}))$$

- Intensive margin: The optimal amount of R&D spending satisfies:

$$\frac{\partial V(s_{jt})}{\partial rd_{jt}} = 0$$

The Variable Cost of Innovation

Structural Parameters for Variable Cost of Innovation			
	θ_1	θ_2	σ_ν
High-Tech Industries			
Chemicals	0.014 (0.001)	0.006 (0.001)	0.157 (0.002)
Metals	0.586 (0.011)	0.024 (0.001)	0.530 (0.008)
Non elect machinery	0.511 (0.008)	2.94E-5 (5.69E-6)	0.151 (0.002)
Electrical machinery	0.424 (0.005)	7.27E-4 (1.06E-5)	0.138 (0.002)
Instruments	0.119 (0.002)	0.014 (0.001)	0.168 (0.003)
Vehicles	0.664 (0.012)	0.011 (0.001)	0.571 (0.008)
Low-Tech Industries			
Food	0.824 (0.012)	0.040 (0.001)	0.206 (0.003)
Textiles	0.184 (0.003)	0.405 (0.005)	0.162 (0.002)
Paper	0.058 (0.001)	0.777 (0.013)	0.112 (0.002)
Plastics	0.477 (0.001)	0.029 (0.001)	0.178 (0.003)
Ceramics	6.21E-7 (9.08E-9)	0.565 (0.008)	7.85E-8 (1.21E-9)
Miscellaneous	0.453 (0.007)	0.235 (0.004)	0.083 (0.001)

- Increasing marginal cost of innovation $\theta_2 > 0$
- Substantial heterogeneity across firms and time

Expected Benefit of R&D

The Expected Benefit of R&D $\Delta EV / R\&D$ (median)		
	Non-exporters	Exporters
High-Tech Industries		
Chemicals	0.711	52.863
Metals	3.428	7.951
Non elect machinery	0.687	49.130
Electrical machinery	0.549	22.104
Instruments	0.568	25.717
Vehicles	1.726	12.423
Low-Tech Industries		
Food	3.028	10.210
Textiles	2.100	4.758
Paper	5.662	11.700
Plastics	1.758	6.002
Ceramics	2.678	17.184
Miscellaneous	3.528	10.146

- Overall, the distribution across exporters stochastically dominates the distribution for non-exporters

Export Tariff Counterfactual

Table 13a: Policy Experiment: The Impact of a 10% Export Tariff

	Proportional Change		Change in Probability		
	ENB	R&D	Maintain	Start	Export
High-Tech Industries					
10th Percentile	-0.397	-0.127	-0.045	-0.070	-0.094
Median	-0.186	-0.076	-0.000	-0.007	-0.000
90th Percentile	-0.043	-0.019	-0.000	-0.000	-0.000
Low-Tech Industries					
10th Percentile	-0.359	-0.087	-0.074	-0.050	-0.088
Median	-0.206	-0.055	-0.007	-0.005	-0.035
90th Percentile	-0.035	-0.011	-0.000	-0.000	-0.000

$$ENB = \Delta EV(s_{jt}) - C_I(rd_{jt}, \upsilon_{jt}, I(rd_{jt-1}))$$

- Substantial effect on intensive margin of R&D investment, less on the extensive margin
- Aggregating across firms, total R&D spending falls by 8.2% in HT and 6.2% in LT

Tariff Impact Across Firms with Different Productivities

Table 13b: Proportional Change in Expected Net Benefit of R&D Investment (ENB)				
Quartile of μ	Q_1	Q_2	Q_3	Q_4
High-Tech Industries				
$P_0 \leq \omega \leq P_{25}$	-0.022	-0.285	-0.381	-0.384
$P_{25} < \omega \leq P_{50}$	-0.058	-0.234	-0.265	-0.246
$P_{50} < \omega \leq P_{75}$	-0.084	-0.187	-0.205	-0.208
$P_{75} < \omega \leq P_{100}$	-0.083	-0.136	-0.154	-0.184
Low-Tech Industries				
$P_0 \leq \omega \leq P_{25}$	-0.054	-0.213	-0.269	-0.318
$P_{25} < \omega \leq P_{50}$	-0.091	-0.174	-0.274	-0.330
$P_{50} < \omega \leq P_{75}$	-0.117	-0.180	-0.236	-0.306
$P_{75} < \omega \leq P_{100}$	-0.123	-0.187	-0.203	-0.256

Firms with high export market productivity are most heavily affected

Impact of an R&D Subsidy to Variable Cost

Table 15a: Policy Experiment: The Impact of 20% Variable R&D Cost Reduction

	Proportional Change		Change in Probability		
	ENB	R&D	Maintain	Start	Export
High-Tech Industries					
10th Percentile	0.006	0.020	0.000	0.001	0.000
Median	0.042	0.074	0.000	0.003	0.000
90th Percentile	0.277	0.256	0.021	0.008	0.001
Low-Tech Industries					
10th Percentile	0.001	0.003	0.000	0.000	0.000
Median	0.011	0.022	0.000	0.000	0.000
90th Percentile	0.076	0.208	0.004	0.002	0.000

- Substantial effect on the intensive margin of R&D investment, much less on the extensive margin
- Industry benefit/cost ratio for the subsidy is 5.67 in HT and 3.12 in LT

Summary and Conclusions

- General Framework
  - Provides a natural measure of the expected long-run payoff from investing in R&D- ΔEV
  - Can be estimated with micro data on firm R&D, inputs/output
  - Provides a basis for counterfactual simulations of R&D choice
- Export Application
  - Exporting firms have larger net benefits from investing in R&D
  - Endogenous mechanism that leads to more R&D and higher productivity for exporters
  - Barriers to trade have a substantial negative impact on return to R&D for Swedish exporters