R&D Investment, Exporting, and Productivity Dynamics

Replication Project for Econometrics II
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1 Summary

This paper addresses four different questions. First, it investigates how past exporting and R&D affect productivity of the firm. Second, it analyzes how past productivity of the firm affect's its decision to engage in exporting or investing in R&D, and whether these two decisions are interdependent. Third, it investigates how sunk cost and fixed cost of exporting are compared to each other, and whether these costs are heterogeneous. Finally, it assess how trade liberalization, which reduces the trade cost or expands market export, affects probability of firm investment in R&D and export. Implication of liberalization has long been among top questions of economists. If liberalization increases consumer welfare and quality of product, risk averse countries may decide to adopt it. This research is conducted in response to mixed evidence in literature about feedback effects of exporting and R&D on future path of firm productivity. Previous empirical evidence showed that firm's decision to export is affected by firm's productivity, firm's size, and firm's ownership states. Moreover, literature suggested that firm's decision to export works as substitute to firm's investment in R&D because firm learns by exporting. To answer this question this paper uses dynamic structural model of producer's decision to invest in R&D and export. It allows both choices to be endogenous to affect firm's productivity. Endogenizing productivity and firm's decision to export and R&D removes selection bias problem that cast doubt on the findings of the previous research by the same author on the same topic in 2007.

They leveraged Taiwanese electronic industry data for a period of 2000-2004, and find out that both the decision to export and the investment in R&D positively affects future productivity of the firm. They further find out that higher future productivity in turn drives plant's to self-select into both of these activities. In order to answer the question about the effect of trade liberalization, based on counterfactual simulation, they find out that an expansion of the export market increase both exporting and R&D investment, and it generates a gradual within plant productivity improvement. They assume firms are strategic, so they account for future benefits of productivity increase. In each of these dynamic decisions, firm will consider marginal benefit, sunk cost and fixed cost. Sunk costs are considered as cost of starting an activity when firm previously had not engaged in the activity, and fixed cost is considered as cost of maintaining an activity. For export market they also allowed separate demand shock for the export market. They observed firm's export market participation, discrete R&D investment, capital stock, domestic/export market revenue, and material and energy expenditure. However, they did not observe productivity, sunk and fixed cost of both R&D and export decision, and export market shock. In order to estimate their dynamic structural model they use two-stage estimation process. In the first stage they estimate underlying process for producer productivity, and in the second stage, using result of the first stage; they estimate dynamic decision of R&D, and export market participation of the firm. Second stage of their estimation gives costs and marginal benefits parameters. They further compare their result, with the result of reduced model estimation.

They find out that marginal benefit of both R&D and export investment increase with plant's productivity. Sunk cost of beginning either activity is greater than the fixed cost of maintaining it. Sunk and fixed cost of investing in R&D are greater than sunk and fixed cost of exporting. Both decisions do not have significant interaction, and firm heterogeneity explains the effect of productivity on R&D and export investment. In their structural model they made lots of assumptions. First they capture heterogeneity of firms only in terms of productivity, and export demand curve, but they do not account for other fixed effect or slope heterogeneity. They assumed that firm's decision consists of two components: static component of productivity effect on export short-run profit, and dynamic effect of optimal R&D and exporting decisions, and they assume that firms are optimizing, but we know that in real words many firms use heuristics rather than optimization method. They assumed firm is single output that is sold in domestic and export market that are monopolistically competitive and segmented from each other. However, in real world firms have multiple products, so they engage in product differentiation by producing different product in domestic and export markets. They assumed the demand curve complies Dixit-Stiglitz form, but there is not enough evidence to show why it is multiplicative rather than additive. They assume that firm maximizes sum of domestic and export profit, but we know that firms usually engage in portfolio profit maximization rather than suboptimization.

They assume that since the time series are short capital stock of firm are fixed, but in real word firms may use financial market to change their capital stock when they have successful R&D project. Moreover, they assumed that aggregate state variable are exogenous and it complies first order Markov process, but if the market has high concentration this assumption is strong. They assume that entering an export market or conducting R&D requires non-recoverable sunk costs, but firms can actually sell their equipment or office at salvage value. They furthermore assume that productivity evolves over time as Markov process that depends on R&D, export and random shock that is exogenous to the model and that has no correlation with

R&D and export status and productivity of previous moment. This is a strong assumption, for possibility of correlation of many omitted variables on R&D export, and economy of scale and scope. They assumed discrete decision of R&D and export result in the same level of increase in productivity, but again this may not be reasonable. R&D and export expenditure may differ across firms because they have different opportunities and expertise, but since they do not observe these opportunities and expertise they assume them to be distributed identically and independently, which is a strong assumption. Finally, they also assume firms go through a sequential decision making process. In the first stage the firm decides about export, and on the second stage it decides about R&D, but this process may be different in different firms.

2 Methodology

They assumed two processes are involved in this dynamic: first production evolution, and second the investment decisions. They assumed firms are heterogeneous in their unobserved productivity, capital stock and export demand curve, and their decisions consists of static component of productivity impact on export market short-run profit, and dynamic component of market optimal R&D and exporting decision. Firm sell single output in both domestic and export market. In order to calculate firm's optimization function, we need to know marginal cost and demand function. They explain marginal cost (c_{it}) of firm i in year t in terms of firm's capital stock (k_{it}), vector of input price common to all the firms (w_t), and productivity (ω_{it}) per following equation:

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

As we can see productivity is assumed to reduce marginal cost of production. They assume marginal cost does not vary with the output level, i.e. demand shcok will not affect the static output decision, which is a strong assumption. They assume both domestic and export markets are monopolistically competitive and segmented from each other. They assume demand function complies Dixit-Stiglitz form, and is function of industry aggregate output (Q_t) and industry aggregate price (P_t^D), jointly called industry aggregate (Φ_t^D), for both domestic (D), and export (X) market. Moreover, demand in the export market is function of firm specific unobservable demand shifter (z_{it}) as follows:

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

where η_D, and η_X are constant elasticity of demand for domestic and export market common across firms respectively. From this marginal cost and demand function they wrote first order condition to find optimal revenue of the firm in domestic and export market in the following form:

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

As a result short run profit of the firm in the domestic and export market that determines firm's decision to export and to invest in R&D in the dynamic model is calculated as follows:

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

Although firms do not perform optimally in the real world they assume that firm choose prices in each market that maximizes the sum of domestic and export profits. Capital stock of firm is assumed to be fixed for the short time series data they have. Aggregate state variables $ln(\Phi^D)$ and $ln(\Phi_t^X)$ are treated as exogenous first order Markov process by time dummies control. Firm is assumed to be strategic, forward looking, when making decision about export and R&D investment. Entering an export market or conducting R&D requires a non-recoverable sunk cost. Productivity is endogenously determined by firm's export and R&D decisions. They assume productivity level(ω_{it}) evolves over time as a Markov process that depends on lagged productivity level (ω_{it-1}), and lagged decision of R&D (d_{it-1}), export (e_{it-1}), and their interaction as follows:

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

where ξ_{it} represent stochastic nature of productivity shock. It is assumed to be independently identically distributed with variance σ_ξ^2. They assume this shock is random and orthogonal to lagged productivity, export and R&D

decision. Here also they assume that discrete decision of export and R&D shifts productivity with the same level across firms. They further assumed export demand shock complies first order autoregressive process, first order Markov process that captures persistence, with serial correlation parameter ρ_z, and standard deviation for the transitory shock of σ_μ^2 as follows:

$z_{it} = \rho_z z_{it-1} + \mu_{it}$

They assumed this this structure for export demand shock because of nature of firm's product, set of countries firm exports to, and long term contractual or reputation of the firm are persistent during time. This sums up the state vector of firm's dynamic decision (s_{it}) as follows:

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

Another strong assumption they made her is that four expenditures are i.i.d., although expenditures are usually different across firms because firms are different in technological opportunities and expertise, so there is a common factor. Bellman equation for firm's decision to invest in exporting or R&D, resulting from tradeoff between relevant marginal benefits and relevant fixed and sunk cost, for the firm can be written as follows:

1. Firm's value function before firm observes its fixed and sunk cost:
$V_{it}(s_{it}) = \int(\pi_{it}^D + max_{e_{it}}\{\pi_{it}^X - e_{it-1}\gamma_{it}^E - (1-e_{it-1})\gamma_{it}^S + v_{it}^E(s_{it}), v_{it}^D(s_{it})\})dG^\gamma$

2. Value of exporting firm after it makes its optimal R&D decision:
$V_{it}^E(s_{it}) = \int(max_{d_{it}}\{\delta E_t V_{it+1}(s_{it+1}|e_{it} = 1, d_{it} = 1) - d_{it-1}\gamma_{it}^I - (1 - d_{it-1})\gamma_{it}^D, \delta E_t v_{it+1}(s_{it+1}|e_{it} = 1, d_{it} = 0)\})dG^\gamma$

3. Value of exporting firm after it makes its optimal R&D decision:
$V_{it}^E(s_{it}) = \int(max_{d_{it}}\{\delta E_t V_{it+1}(s_{it+1}|e_{it} = 1, d_{it} = 1) - d_{it-1}\gamma_{it}^I - (1 - d_{it-1})\gamma_{it}^D, \delta E_t v_{it+1}(s_{it+1}|e_{it} = 1, d_{it} = 0)\})dG^\gamma$

4. Value of nonexporting firm after it makes its optimal RD decision:
$V_{it}^D(s_{it}) = \int(max_{d_{it}}\{\delta E_t V_{it+1}(s_{it+1}|e_{it} = 0, d_{it} = 1) - d_{it-1}\gamma_{it}^I - (1 - d_{it-1})\gamma_{it}^D, \delta E_t v_{it+1}(s_{it+1}|e_{it} = 0, d_{it} = 0)\})dG^\gamma$

where γ_{it}^E is fixed cost of exporting, γ_{it}^S is sunk cost of export market entry, γ_{it}^I is fixed cost of R&D, and γ_{it}^D is sunk cost of R&D. This will give us the expected value conditional on different choices of R&D and export as follows: $E_t V_{it}(s_{it}|e_{it}, d_{it}) = \int_{\Phi'} \int_{z'} \int_{\omega'} v_{it+1}(s) dF(\omega'|w_{it}, e_{it}, d_{it}) dF'(z'|z_{it}) dG(\Phi'|\Phi_t)$

Dynamic decision of firm for R&D and export is formed by comparing fixed and sunk cost with marginal benefit. As a result we can calculate marginal benefit of R&D, and marginal benefit of exporting respectively as follows:

$$MBR_{it}(s_{it}|e_{it}) = E_t V_{it+1}(s_{it+1}|e_{it}, d_{it} = 1)$$
$$MBE_{it}(s_{it}|d_{it}) = \pi_{it}^X(s_{it}) + V_{it}^E(s_{it}|d_{it-1}) - v_{it}^D(s_{it}|d_{it-1})$$

Therefore, difference in future benefit of R&D between exporter and non exporter, and incremental impact of R&D on the return to exporting can be calculated respectively as follows:

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

For estimation they use two-step method. In the first step they estimate parameters of productivity evolution and domestic revenue function jointly to construct measure of firm productivity. In the second stage they estimate dynamic discrete choice model of the export and R&D decision. Outcome of second stage is fixed and sunk cost of both exporting and R&D, and export revenue parameters. Therefore full set of parameters they estimate include the following:

$$\eta_X, \eta_D, \Phi_t^X, \Phi_t^D, \beta_0, \beta_k, \beta_w, g(w_{it-1}, d_{it-1}, e_{it-1}), \sigma_\xi^2, G^\gamma, \rho_z, \sigma_\mu^2$$

where $g(w_{it-1}, d_{it-1}, e_{it-1})$ is a function of productivity evolution, and G^γ represents distribution of fixed and cost of exporting and R&D.

In the first stage of their estimation they use from the assumption that higher productivity translates into saving in input factors, such as material (m_{it}), and electricity (n_{it}), so by assuming a cubic function of these input factors and capital stock they recover revenue, and productivity series ϕ_{it} which is estimate of $(\eta_D + 1)(\beta_k lnk_{it} - \omega_{it})$ as follows:

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

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

$h(k_{it}, m_{it}, n_{it}) + \upsilon_{it}$

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

Then they use productivity evolution equation, and using the assumption that marginal cost is equal to marginal revenue, using marginal cost data, they estimate price elasticities and parameters of productivity evolution equation as follows:

$\hat{\omega}_{it} = -\frac{1}{(\hat{\eta}_D+1)}\hat{\phi}_{it} + \hat{\beta}_k lnk_{it}$
$tvc_{it} = q_{it}^D c_{it} + q_{it}^X c_{it} = r_{it}^D(1 + \frac{1}{\eta_D}) + r_{it}^X(1 + \frac{1}{\eta_X}) + \epsilon_{it}$

Intuitively in the second stage of estimation from data of entry and exit from the export market they recover parameter of sunk cost of entery (γ_{it}^S) and fixed cost γ_{it}^E. From discrete choice of R&D they recover fixed (γ_{it}^I) and sunk cost (γ_{it}^D) of R&D, and from level of export revenue they recover demand shock z_{it} conditional on exporting. Input data for second level of estimation is export market participation discrete decision $e_i = (e_{i0}, \ldots, e_{iT})$, R&D investment discrete decision $d_i = (d_{i0}, \ldots, d_{iT})$, export revenue $r_i^X = (r_{i0}^X, \ldots, r_{iT}^X)$, and unobserved firm level productivity series from first stage of estimation $\omega_i = (\omega_{i0}, \ldots, \omega_{iT})$.

For the second stage they calculate firm's contribution to the likelihood function as follows, that they will simulate based on joint distribution of R&D, and export decisions:

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

Therefore the probability of exporting and investing in R&D is derived as follows:

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

$P(d_{it} = 1 | s_{it}) = P(d_{it-1}\gamma_{it}^I + (1 - d_{it-1})\gamma_{it}^D \leq \delta E_t V_{it+1}(s_{it+1} | e_{it}, d_{it} = 1) - \delta E_t V_{it+1}(s_{it+1} | e_{it}, d_{it} = 0))$

In order to estimate the model they evaluated the likelihood function for each set of parameters rather than attempt to maximum likelihood. They utilized a Bayesian Markov Chain Monte Carlo Estimator for 20,000 iterations, in replication I used only 2,000 iterations after converting their FORTRAN code to MATLAB, and it took me 3 days to get results. The parameters they estimate using MCMC include the following:

$$\Theta = (\gamma^I, \gamma^D, \gamma^F, \gamma^S, \Phi^X, \rho_z, \sigma_\mu, \theta_0^e, \theta_0^d)$$

Their objective in the second stage of estimation is to characterize the posterior distribution of dynamic parameters, and they jointly estimate it with a probit function to estimate initial points (θ_0^e, θ_0^d). They assume each of the four costs draw from separate independent exponential distribution, and they allow heterogeneity by separately estimating these exponential distributions for large and small firms. In their estimation they evaluate each plant's conditional choice probability of export $(p(e_{it}|s_{it}))$, and R&D (p(d$_{it}|s_{it})), wherestatevectorisrepresentedby$s$_{it} = (\omega_{it}, z_{it}, k_i, \Phi_t, e_{it-1}, d_{it-1})$.

Their estimation algorithm is as follows: first they begin with initial guess and 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. Then they calculate V_t^{E0}, and V_t^{D0}, and $V^1(s)$ as following, and they iterate across previous two steps until $|V^{j+1} - V^j| < \epsilon$. Since their state space is very large, they use John Rust's discretization method for state space $N = 100$.

To do so, they denote random grid points $(\omega_1, z_1), \ldots, (\omega_n, z_n), , (\omega_N, z_N)$ and solve dynamic problem and value function $(\hat{V})$ on grid points by function iteration method. For this estimation the assume mean of costs have prior distribution of $N(0, 1000)$, and auto regression coefficient in export demand shock has prior distribution of $U(-1, 1)$. Their method they used for initial point problem is Heckman's solution of using separate probit equation.

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

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

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

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

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

Table 1: Annual Transition rates for Continuing Plants

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

This closes the methodology section of this summery report.

3 Replication of findings

Figure 1 below illustrates annual transition rate for continuing plants, i.e. those firms that do not exit. We can observe that most firms remain in their previous state, showing high persistence.

Table 2 presents result of first stage of estimation process, including demand and productivity evolution parameters. Almost all the parameters except log capital has positive impact on the productivity.

Table 3 illustrates the reduced form model estimation of export and revenue. It shows that high productivity results in firm self-selection into exporting and R&D investment. Results remain the same after accounting for fixed effect results.

Result of second stage of estimation process, dynamic parameters, are presented in table 4. As we can see sunk costs are generally higher than fixed costs, and these two costs are higher for R&D explaining why firm are more likely to export than to invest on R&D.

In sample model performance is presented in table 5 and table 6. Both likelihood of investing in R&D and export decisions and transition between different states are close to the actual data.

Table 7 presents marginal benefit of exporting. It shows that this marginal benefit increases with increase in productivity.

Table 8 presents cost of exporting and R&D variation with productivity. It shows that this marginal benefit increases with increase in productivity.

Finally, table 9 presents result of counterfactual analysis of plant's

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

Table 2: Result of first stage of estimation, including demand and productivity evolution parameters

Dependent variable	Prod.(ω_{it})	Capital(k_{it})	Lg Exp.(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)*			$Var(z) = 0.72$

Table 3: Reduced form model estimation for export and R&D participation and export revenue

Means and standard deviations of the posterior distribution					
Model 1 (Same cost distrib.)			Model 2 (Heterog. in cost distrib.)		
Parameter	Mean	STD	Parameter	Mean	STD
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

Table 4: Dynamic Parameters Estimates

	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

Table 5: In sample model performance for likelihood of firm decision to invest in R&D or export

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

Table 6: In sample model performance for state transition probability

	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

Table 7: Marginal Benefit of Exporting (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

Table 8: Costs of Exporting and R&D variation with productivity(Millions of NT dollars)

	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

Table 9: Costs of Exporting and R&D variation with productivity(Millions of NT dollars)

response to exogenous increase in export market size. It shows that the effect is much higher if the model accounts for endogeneity of productivity.

4 Discussions

This research starts with an important question about effect of market liberalization policy. Using manifold assumptions, it develops a structural model that is not dependent on the current policy regime observed on the data. This model allows them to simulate counterfactual and find that market liberalization positively affects investment in R&D and export. Some of the assumptions are strong such as assuming that marginal cost does not vary with output level that requires that demand shock not affect the static output decision. Assuming that all four types of costs are i.i.d. is also questionable, because firms are common factor for these costs and different technological opportunities for firms create correlation between these expenditures. Assuming that productivity shock is orthogonal to lagged productivity, R&D and export decision of firm is also pretty strong assumption. Moreover, it is questionable to assume that discrete decision of R&D and export result in the same level of increase in productivity. Overall, as Sam's said, there are complex problems in real world that only by too much assumption we can find a solution. This is not comparable to random experiment, but it is the best possible solution using limited data. Results sound reasonable, because R&D and export both increase firm productivity, based on learning by doing theory. Self-selection of high productivity strategic firms into R&D and export also sounds good. It is trivial not trivial that sunk cost is always lower than operation cost, but for this industry it may not be questionable. Higher marginal benefit for high productivity firm can also be explained by reproductively of resources that a firm possesses. Higher R&D costs that export cost may also be explained by scarcity of resources, so it is reasonable. Importance of heterogeneity is also common sense.   All in all, their estimation method is interesting, although with multitudinous questionable assumptions. The way they attacked selection bias may not be the best way, but counterfactual analysis and independence from policy regime is plausible feature of their method. They fulfilled their promises they plot out in the abstract of the paper, and generally their results sounds cogent.