Time to Build and Fluctuations in Bulk Shipping

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This Paper

How important are production lags in affecting industry dynamics?

- Broad literature on investment under uncertainty with adjustment costs.
- But little empirical evidence on quantitative importance of specific mechanisms.

Main result

- Adjustments cost in the form of time to build affect 1st and 2nd moments: reduces entry and fleet levels and volatility, and raises prices of trips.

Empirical strategy

- second-hand sale prices of ships can be used to non-parametrically estimate value functions and then recover per-period profits and entry/exit costs.
- "mirror-image" of Bajari, Benkard, Levin (2007).

Environment

A ship is a firm and its state is its age j and the industry state $x_t = (s_t, b_t, d_t)$

- $s_t = [s_t^0, \ldots, s_t^A]$ is the industry age distribution , $b_t = [b_t^1, \ldots, b_t^{\bar{T}}]$ is the backlog of ship orders, d_t is a demand shifter for trips (exogenous 1st order Markov).

Upon entry, ships are assigned a time to build $T_t(s_t, b_t, d_t)$. Timing is as follows:

1. Exit/entry decisions are made simultaneously.
   - Incumbents observe scrap value $\phi \sim F_\phi$ every period and decide to stay/exit.
   - Potential entrants observe entry cost $\kappa(s_t, b_t, d_t)$ and decide to stay out/enter (first empirical paper to allow for non-iid state dependent entry costs).
2. Incumbents receive per-period profits $\pi_j(s_t, d_t)$, even if they've decided to exit.
3. Entry/exit decisions are implemented and the state evolves.

- Value of an age j incumbent at t before observing ϕ

$$V_j(s_t, b_t, d_t) = \pi_j(s_t, d_t) + \beta E_\phi \max\{\phi, VC_j(s_t, b_t, d_t)\}$$

where $VC_j(s_t, b_t, d_t) \equiv E[V_{j+1}(s_{t+1}, b_{t+1}, d_{t+1}) | s_t, b_t, d_t]$ and $E[\cdot]$ is an expectation over entrants N_t and age j exiters Z_t^j.

$$\begin{aligned}
s_{t+1}^0 &= b_t^1 \\
s_{t+1}^j &= s_t^{j-1} - Z_t^j && j = 1, \ldots, A \\
b_{t+1}^i &= b_t^{i+1} && i \neq T_t, \bar{T} \\
b_{t+1}^{T_t} &= b_t^{T_t+1} + N_t, \quad , b_{t+1}^{\bar{T}} = 0 && T_t < \bar{T} \\
b_{t+1}^{\bar{T}} &= b_t^{\bar{T}} + N_t && T_t = \bar{T}
\end{aligned}$$

- Value of entry is $VE(s_t, b_t, d_t) \equiv \beta^{T_t} E\left[V_0(s_{t+T_t}, b_{t+T_t}, d_{t+T_t}) | s_t, b_t d_t\right]$ and there is an entry cost $\kappa(s_t, b_t, d_t)$.

Equilibrium assumptions:

1. Potential entrants play a symmetric mixed entry strategy $\implies N_t$ is well approximated by a Poisson with entry rate $\lambda(s_t, b_t, d_t)$.
2. Equilibrium is symmetric $\implies$ incumbents use a common cut-off rule for exit, which induces an exit probability $\zeta(s_t, b_t, d_t)$.

Equilibrium

Let $V_j(x;\zeta',\zeta,\lambda)$ be the incumbent's payoff from playing ζ' given others play ζ.

$$V_j(x;\zeta',\zeta,\lambda) = \pi_j(s_t,d_t) + \zeta'\beta E\left(\phi|\phi > VC_j(x;\zeta,\lambda)\right) + (1-\zeta')\beta VC_j(x;\zeta,\lambda)$$

An equilibrium is an entry strategy λ and an exit strategy ζ such that

- Incumbent firm strategies represent a MPE.

$$\sup_{\zeta_j'(x)\in[0,1]} V_j(x;\zeta',\zeta,\lambda) = V_j(x;\zeta,\zeta,\lambda) \quad \forall j \in \{0,1,\ldots,A\}, x \in (S \times B \times D)$$

- Entrants have zero expected profits or entry rate is zero (or both).

$$VE(x) \leq \kappa(x) \quad \forall x \in (S \times B \times D) \quad \text{with equality if } \lambda(x) > 0$$

Data

1. Second-hand sales data $\rightarrow$ used to estimate value functions.
2. Contracts data on prices and quantities of trips $\rightarrow$ used to estimate trips demand.
3. Ship orders, deliveries, demolitions $\rightarrow$ used to estimate state transitions.

Empirical strategy

Main challenge in dynamic games is computing continuation values.

- Second-hand sale prices are used to recover value functions nonparametrically $\Longrightarrow$ need to assume homogenous agents, no private info, no search frictions, so that sale price $=$ ship value.

Two step procedure:

1. Estimate value functions, state transitions, and exogenous objects not determined in equilibrium (d_t and T_t) "outside" of the model.
2. Given estimates in 1, use the model's restrictions to estimate primitives: profits, scrap value distribution, entry costs.

Step 1

- Estimate demand for trips using supply shifters (fleet size/age, fuel costs).
- Estimate $V(\cdot)$ using local linear regression on re-sale prices and grid $[j, X]$.

$$\min_{\beta_0,\beta_j,\beta_S,\beta_B,\beta_d} \sum_i \{p_i^{SH} - \beta_0(j,X) - \beta_j(j,X)(j_i - j) - \beta_S(j,X)(S_i - S)$$
$$- \beta_B(j,X)(B_i - B) - \beta_d(j,X)(d_i - d)\}^2 K_h([j_i, X_i] - [j, X])$$

- Estimate TTB running OLS of T_t on X_t.
- Estimate transition of X_t assuming conditional independence between N_t, Z_t, ϵ_t

$$Pr(x_{t+1}|x_t) = Q(x_t, x_{t+1}) f_N(N_t = n|x_t) f_Z(Z_t = z|x_t) f_\varepsilon(\epsilon_{t+1})$$

Project entry/exit rates ζ_t, λ_t on X_t to compute conditional densities $f_N(\cdot|X_t), f_Z(\cdot|X_t)$. Use demand parameters to compute ε_{t+1}.

Step 2

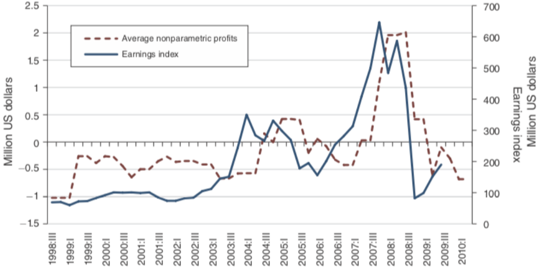
- Given P,V from step 1 we can compute $VC_A = PV_A$, and if we assume only age A ships may exit then the share of exiters is $\frac{Z_t}{s_t^A} = 1 - F_\phi(VC_A(X_t))$. We then run local linear regression at all points of interest ν.

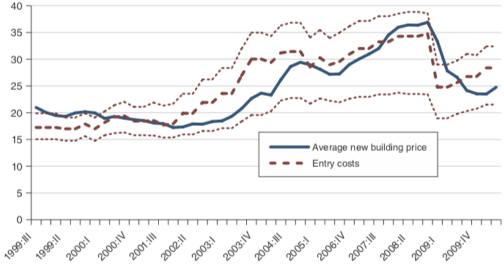
$$\min_{\beta_0, \beta_{VC}} \sum_t \left[\frac{Z_t}{s_t^A} - \beta_0(\nu) - \beta_{VC}(VC_A(X) - \nu) \right]^2 K_h(VC_A(X) - \nu)$$

  so that $1 - F_\phi(\nu) = \beta_0(\nu)$.
- Profits backed out as $\pi_j = V_j - \beta VC_j$ and entry costs backed out from free entry condition

$$\beta^{T(X)} P_X^{T(X)} V_0 = \kappa(X)$$

Model fit


Average nonparametric profits
Earnings index
Million US dollars
Earnings index
Million US dollars


Average new building price
Entry costs

Counterfactuals

- Profits are parametrized by cost parameters θ.
- Under perfect competition in the spot market for trips, firms optimize and obtain $\pi(\theta) \implies \theta$ can be estimated via NLLS using non-parametric $\hat{\pi}$ from step 2.
- We can now compute counterfactual equilibria, i.e., solve for λ, μ, V given primitives θ, κ, F_ϕ. Two counterfactuals considered: constant and no TTB.
- Experiment 1: impulse response to a positive demand shock.
- Experiment 2: long-run industry dynamics.

Impulse response to positive demand

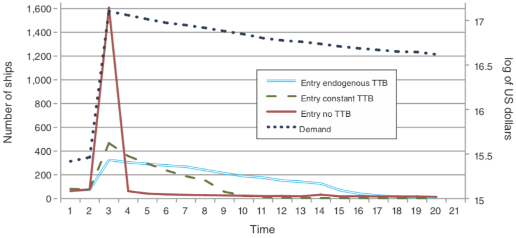


Figure 14. Entry Under Endogenous, Constant, and No Time to Build (TTB)

Note: Demand depicted on right axis.

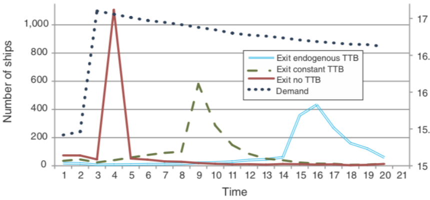


Figure 15. Exit under Endogenous, Constant, and No Time to Build (TTB)

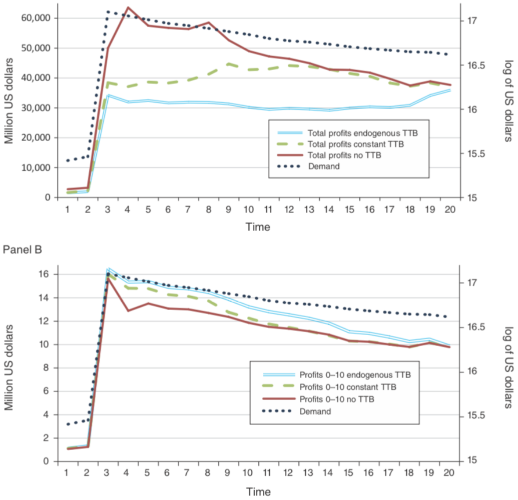


Figure 18. Total (*sum of*) and per Ship Profits for All Age Groups under Endogenous, Constant, and No Time to Build (TTB)

Long run dynamics

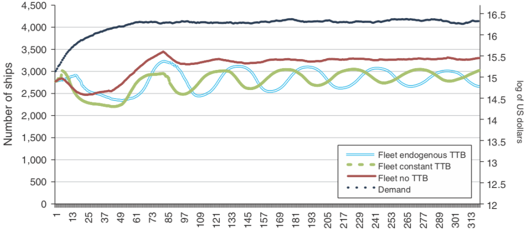


Figure 20. Average Fleet from Long-Run Simulations

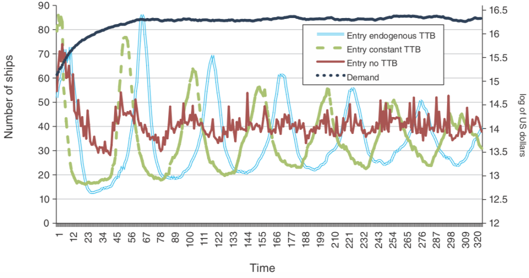


Figure 21. Average Entry from Long-Run Simulations

- Echo effects vanish quickly when there is no TTB

Conclusion

Methodology

- with homogenous agents, observed transaction prices of a good whose value is the solution to a dynamic problem can be used to estimate dynamic parameters.

Economics

- Much work on investment under uncertainty considers comparative statics in demand uncertainty, broadly defined.
- But then what specific policies should we think of to affect demand uncertainty, especially in the context of trade?
- This paper quantifies a specific channel which affects investment, so we can think of obvious policy implications (e.g. building more shipbuilding docks).