Learning and Investment under Demand Uncertainty in Container Shipping

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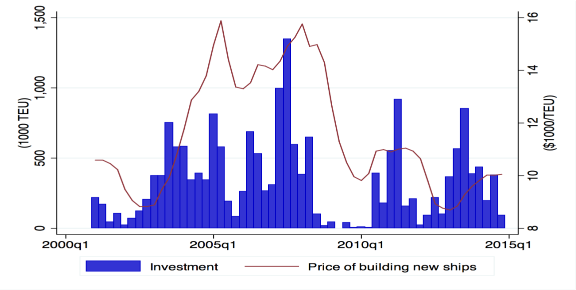
Boom and Bust Cycles of Investment

- Many capital-intensive industries experience large waves in investment: e.g. chemicals, oil-exploration, real estate.
- Firms invest in long-lived capital under high demand fluctuations → Important role of demand forecasts.
- Investment and shipbuilding prices in container shipping.



  - Sharp swings in trade demand + Inelastic short-run supply.
  - Heavy investment during demand boom → Excess capacity after 2008 crisis.

This Paper

- Focus on the role of information to understand boom-bust investment cycles in a setting with market power and strategic considerations.
- The standard full-information approach: agents know the true data-generating process so that the only uncertainty is about demand realizations.
- Incorporates uncertainty about the demand process as well.

Motivation for Learning

- Industry experts attribute excess capacity to firms' inability to forecast demand: *"[T]he industry extrapolated the good times and foresaw an unsustainable rise in demand." -Mckinsey Insights, 2014*
- Studies using learning models to describe agents' beliefs on macroeconomic shocks: Cogley & Sargent (2005), Orlik & Veldkamp (2014).
- Many settings in which the full-info assumption may not be appropriate: e.g. new entrants, policy shocks, other exogenous shocks

Research Questions

- Can a learning model help us explain boom-bust investment cycles?
- How does learning interact with strategic incentives of the firms?
- Does the modeling choice for firms' expectations matter in policy evaluation or welfare analysis?

Overview of Approach

- Propose a dynamic oligopoly framework with learning about aggregate demand.
  - Agents form and revise expectations about demand using available information.
  - Allowed to put heavier weights on more recent obs. (may believe the process changes over time).
  - Compare predictions of my model to those of alternative models of firm beliefs.
- Estimate the model using firm-level data from container shipping.
- Counterfactuals under learning and full information.
  - Competition/ Coordinated investment
  - Demand volatility
  - Scrapping subsidies

Challenges and Strategy

- Challenges:
  - Agents' beliefs are not directly observed.
  - Hard to identify information and model parameters simultaneously (Manski (1993)).
- My Strategy:
  - Use commonly unavailable data on investment & scrap price data $\rightarrow$ Focus on identifying the model of firm beleifs.
  - Consider various alternative models of firm beliefs.
  - Conduct validity test based on GDP forecast data.

Main Results

1. Learning raises the volatility of investment and the correlation between demand and investment.
   - Agents put heavier weights on more recent obs.: 45% weight on a 10 yr. old obs.
   - Confirmed on validity test based on GDP forecast data.
2. Strategic incentives increase both the level and the volatility of investment and that learning intensifies these forces.
3. Learning amplifies investment cycles through
   - leading agents to revise beliefs as they experience demand volatility.
   - intensifying strategic incentives
4. Modeling of firms' expectations has policy implications:
   - Full info model underestimates welfare gains from a merger between top two firms.

Data

- Key ingredients
  - 1997-2014 quarterly route-level data on price and quantity.
  - 2006-2014 quarterly firm-level data on capital, investment, deployment; 17 firms $\times$ 36 quarters $=$ 612 obs.
  - 2006-2014 quarterly industry-level data on shipbuilding, scrap prices.

Model Overview

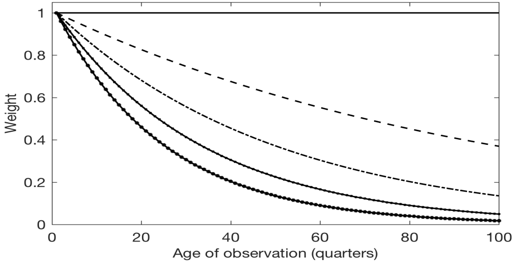
1. Firms' expectations about demand
2. Dynamic problem of firms
3. Product market competition
4. Demand for shipping services

Adaptive Learning Model for Firms' Expectations about Demand

- Firms consider an $AR(1)$ model for demand in Asia-Europe and outside markets:

$$z_t = \rho^0 + \rho^1 z_{t-1} + \omega_t, \quad \omega_t \sim N(0, \sigma)$$
$$\tilde{z}_t = \tilde{\rho}^0 + \tilde{\rho}^1 \tilde{z}_{t-1} + \tilde{\omega}_t, \quad \tilde{\omega}_t \sim N(0, \tilde{\sigma})$$

- Parameters $\eta = \{\rho^0, \rho^1, \sigma, \tilde{\rho}^0, \tilde{\rho}^1, \tilde{\sigma}\}$ unknown. Update beliefs by re-estimating them using $\{z_\tau, \tilde{z}_\tau\}_{\tau=0}^{t}$.
- Agents may be concerned about structural breaks at unknown dates: Allow firms to put heavier weights on more recent obs.



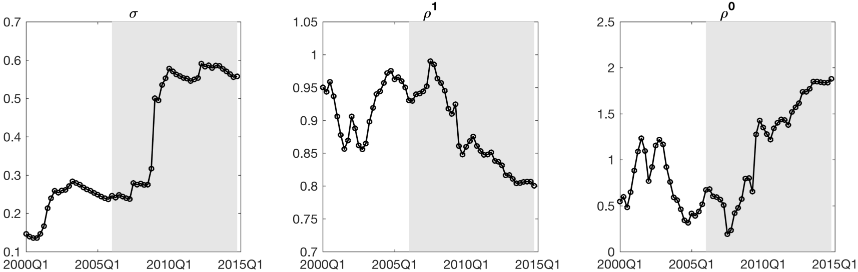
$\lambda_t = \frac{1}{t}$ $\lambda_t = 0.01$ $\lambda_t = 0.02$ $\lambda_t = 0.03$ $\lambda_t = 0.04$

Firms' Problem and Product Market Competition

- Dynamic problem of firms:
  - State: $(k_{it}, b_{it}, \sum_i k_{it}, \sum_i b_{it}, z_t, \tilde{z}_t)$
    k_{it}=owned ship capacity, b_{it}=order book capacity, z_t = A-E demand, $\tilde{z}_t$=outside market demand
  - Dynamic decisions: investment, scrapping
- Product market competition:
  - Firms choose capacity to charter and capacity to deploy in different markets.
- Constant elasticity demand for shipping services

Empirical Implementation of Model of Firm Beliefs

- For each λ_t: Estimate $\{\rho_t^0, \rho_t^1, \sigma_t, \tilde{\rho}_t^0, \tilde{\rho}_t^1, \tilde{\sigma}_t\}$ using $\{z_\tau, \tilde{z}_\tau\}_{\tau=0}^t$ at each t.
- Beliefs under Learning for the Asia-Europe Market for $\lambda_t = 0.02$



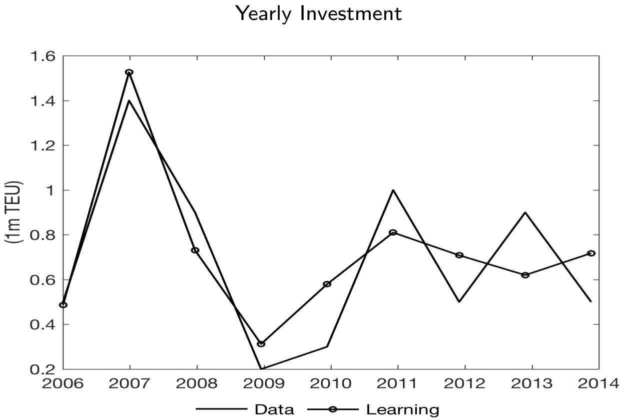
Estimation Overview

1. Demand: price elasticity $\rightarrow$ demand states
2. Supply: MC, charter cost, outside market profit
3. Other primitives: Investment cost, scrap value, delivery process
4. Firms' beliefs and dynamics

Estimation: Dynamic Parameters and Model of Firm Beliefs

- Method of Simulated Moments
  - Moments: Average investment in 2006-2008, 2009-2014, total capacity of owned ships, total capacity in order book, correlation between demand and investment, investment volatility.
- Results
  - Adaptive learning with $\lambda_t = 0.02$ (weight on an obs. from 10 yrs ago = 0.45)
    - 0.0175∼0.02 in Malmendier & Nagel (2016), Milani (2007), Orphanides & Williams (2005)
  - Fixed cost: ∼36% of period profit ($ 25 mil. per 0.1 mil. TEU)
  - $\sigma^{\iota} = 0.275$ bil. US dollars; $\sigma^{\delta} = 0.43$ bil. US dollars

Model Fit of the Learning Model

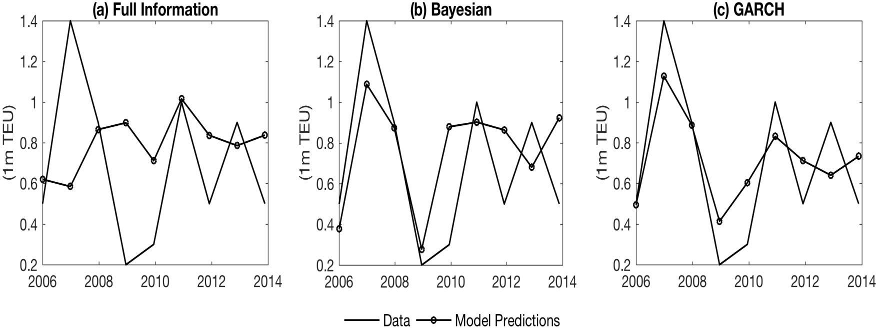


Alternative Models of Firm Beliefs

- Full Information
  - The parameters $\eta = \{\rho^0, \rho^1, \sigma, \tilde{\rho}^0, \tilde{\rho}^1, \tilde{\sigma}\}$ are known to the agents.
  - Estimate the parameters using the full sample of the data (1997:Q1-2014Q4)
- Bayesian Learning
  - Firms start with priors about parameters. Update beliefs based on new information.
- Full Information with time-varying volatility: GARCH(1,1)

$$\sigma_t^2 = a_0 + a_1 \omega_{t-1}^2 + b_1 \sigma_{t-1}^2$$

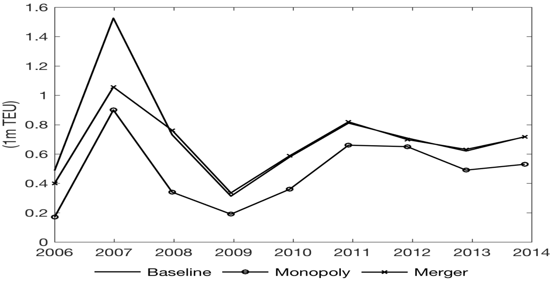
Model Fits under Alternative Models of Beliefs



Counterfactuals (1): Coordination in Investment

- Do strategic incentives increase the level and the volatility of investment? What are the effects of increased consolidation?
  - Theory: business-stealing (e.g. Mankiw & Whinston (1986)) and preemption (e.g. Spence (1977))
  - Trend towards consolidation: 2M Alliance, proposed mergers.
  - In the model:
    1. A firm's deployment of an extra unit of capacity increases its own market share but has a negative effect on the market price and rivals' profits.
    2. An increase in industry order book raises the ship-building price.

Counterfactuals (1): Multi-Plant Monopoly and a Merger by Top 2 Firms



- Strategic interaction increases the level and the volatility of investment.

	Monopoly	Merger
Investment	-33.9%	-7.5%
Volatility of investment	-21.5%	-14.7%
Owned capacity	-23.2%	-2.5%

Counterfactuals (1): Welfare and Policy Implications

- PS gain vs. CS loss
  - Monopoly: \$92 bil. gain in PS; \$42 bil. CS loss in the A-E market.
  - Merger: \$14 bil. gain in PS; \$1 bil. CS loss in the A-E market.
- Does the modeling choice for firms' expectations matter in policy evaluation?

	Merger	
	Learning	RE
Δ in investment (1 mil. TEU)	-0.014	-0.009
Δ in investment volatility (1 mil. TEU)	-0.025	-0.004
Δ in consumer surplus (1 bil. US dollars)	-0.94	-0.46
Δ in producer surplus (1 bil. US dollars)	13.96	10.04
Δ in total surplus (1 bil. US dollars)	13.03	9.58

  - Learning intensifies strategic incentives.
  - Full Info model underestimates welfare gains from the merger.

Counterfactuals (2): Demand Volatility

- Simulate high vs. low demand volatility.

Model	Learning		Full Info	
Volatility	High	Low	High	Low
Investment (1 mil. TEU)	0.15	0.16	0.14	0.16
Std. dev. of investment (1 mil. TEU)	0.08	0.04	0.05	0.03
Corr. between demand and investment	0.10	-0.03	-0.05	-0.16

- Increased volatility reduces investment: Consistent with Bloom (2009), Collard-Wexler (2013).
- Informational channel: Under learning higher demand volatility leads to more drastic revisions of beliefs
  $\rightarrow$ Amplifies investment boom-bust cycles.

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Conclusion

- This paper analyzes boom-bust cycles of investment under demand uncertainty.
- Builds and estimates a dynamic oligopoly model with uncertainty and learning about the demand process.
- Shows:
  1. A learning model in which agents assign heavier weights to more recent obs. can help explain firm behavior in an environment with potential structural changes.
  2. Strategic incentives increase the level and the volatility of investment. Allowing coordinated investment can lead to efficiency gains.
  3. Learning amplifies investment cycles through
     - intensifying strategic incentives
     - leading agents to revise beliefs as they experience demand volatility.
  4. The modeling choice for firms' expectations has policy implications.