ECO 3901
EMPIRICAL INDUSTRIAL ORGANIZATION

Lecture 6
Uncertainty and Firms' Investment Decisions

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Uncertainty and Firms' Investment Decisions: Introduction

- There is a **voluminous theoretical literature** on the impact of irreversibility (adjustment costs) and uncertainty on firm investment decisions.

  Kydland and Prescott (1982); Abel (1983); Caballero (1991); Pindyck (1991, 1993); Dixit (1992); Abel and Eberly (1994); ...

- However, there is still little micro-level empirical work using structural models to evaluate the effects of irreversibility and uncertainty on firms' investment.

- **Cooper & Haltiwanger** (AER, 1999; REStud, 2006) are important contributions to this topic. They assume **monopolistic competition**.

- In this topic, we study more recent work that accounts for **oligopoly competition**.

Outline

1. **Collard-Wexler (ECMA, 2013):**

   Demand Fluctuations in the Ready-Mix Concrete Industry

2. **Kalouptsidi (AER, 2014):**

   Time to Build and Fluctuations in Bulk Shipping

1. Demand Fluctuations in the Ready-Mix Concrete Industry

Collard-Wexler (2013) - Outline

1. Motivation
2. Some features of the concrete industry
3. Data
4. Model
5. Estimation
6. Counterfactuals

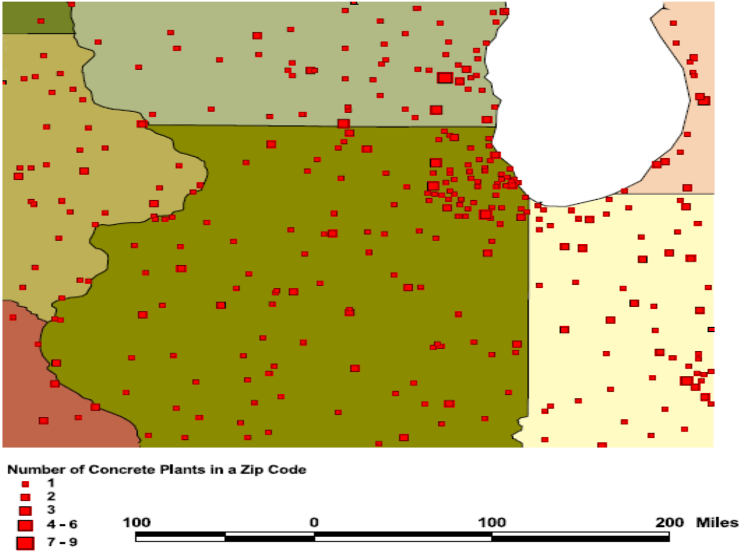
Motivation

- How does **demand uncertainty** affect firms' investments, market structure, and welfare in an industry?
- In industries with substantial **sunk costs** in entry or investment decisions, uncertainty can generate substantial inaction and amplification of shocks.
- Since **sunk costs are not proportional to firm size**, uncertainty affects differently small and large firms. This affects **market structure**, competition, and welfare.
- In some industries (e.g., construction) **goverment activity contributes to demand uncertainty**. Room for policy improvements.

Ready-Mix Concrete Industry

- Collard-Wexler studies this issue in the **US concrete industry** during **1976-1999**.
- Substantial demand uncertainty due to volatility of local construction industries.
- Substantial sunk costs and irreversibility in entry and investment decisions.
- Due to high transportation costs, competition is very local: oligopoly industries.

Location of Concrete plants: Midwest



Local oligopoly competition

- Homogeneous product [Not accounting for spatial differentiation].
- Local market: County (approx. 3,100 counties).
- Most counties have fewer than 6 plants.
- Market price at the county level declines with the number of plants – though becomes quite flat for plants > 4.

  * Note: This descriptive evidence quite likely underestimates true effect of competition on prices: more plants in markets with more demand.

Empirical distribution: number of plants, 1976-1999
Problem with market definition: counties with no plants.

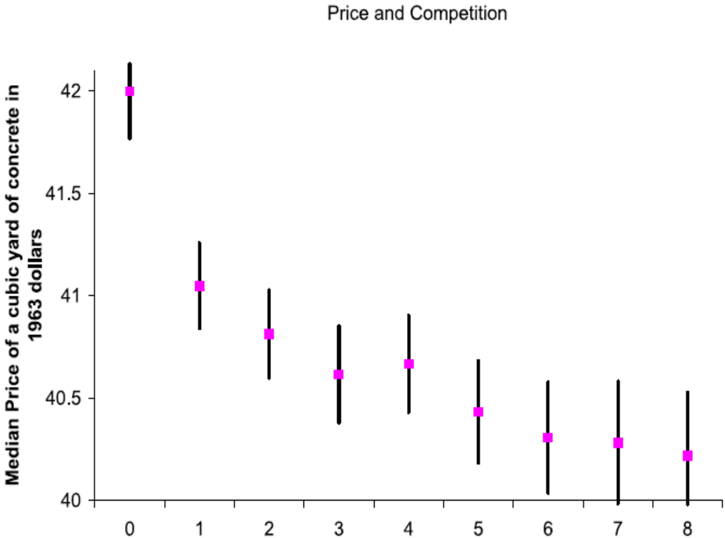
TABLE I

MOST COUNTIES IN THE UNITED STATES ARE SERVED BY FEWER THAN SIX READY-MIX CONCRETE PLANTS

Number of Concrete Plants	Number of Counties/Years	Percent
0	22,502	30%
1	23,276	31%
2	12,688	17%
3	6373	9%
4	3256	4%
5	1966	3%
6	1172	2%
More than 6	3205	4%
Total	74,438	

Median price and number of plants in county

Unobserved market heter. Underest. effect of competition on price.



Demand and uncertainty

- C-W measures (annual) demand using employment in the construction industry at the county level.
- Substantial volatility of demand.
- Approx. 50% of demand for concrete comes from the government: e.g., construction and repairing roads.
- Demand from government is particularly uncertain.

Sunk Costs of Entry

- Based interviews to managers, the entry cost of a new plant is between **$3M and $4M**.
- Land, the Plant itself, and Trucks for distribution to clients.
- **Upon exit**, investments in land and trucks are quite reversible – liquid secondary markets with small transaction costs.
- **Upon exit**, investments in the plant itself are almost completely lost – just scrap metal.
- Sunk costs are substantial: estimate from managers' interviews: **$2M**.

Data

- From the **Longitudinal Business Database (LBD)** of the US Census Bureau: 1976-1999 (24 years).

  - It is a business registry: **includes ALL plants**.

  - Information on NAICS industry, geographic location, entry, exit, employment, and salary. But not on sales, materials, or capital.

- Merge with the **Annual Survey of Manufacturers (ASM)**.

  - Information at the plant level on inputs, outputs, and assets.

  - It is a sample: **includes a small fraction of plants**.

Heterogeneity in plant size

- C-W measures plant size using employment (better measured than capital, and available for all plants).
- **Average plant (in 1997):** 26 workers; \$3.4M in sales.
- Distribution of plant size is very skewed:

# of employees	% of plants
1 employee	5%
$\leq$ 8 employees	28%
$\leq$ 18 employees	66%
$>$ 80 employees	5%

Model: State and decision variables

- Dynamic game of oligopoly competition at the county level.
- k_{it} = endogenous state variable that represents firm size:

$$k_{it} \in \{0, \ 1, 2, 3\}$$

0 = out of the market;
1 = active *small*, with less than 8 workers;
2 = active *medium*, with 8 to 17 workers;
3 = active *large*, with more than 17 workers.

Model: State and decision variables [2]

- d_t = state of demand. Follows a Markov process.

  - A different AR(1) process for each county.

- The vector of observable / common knowledge state variables is:

$$\mathbf{x}_t = (k_{1t}, k_{2t}, ..., k_{Nt}, d_t)$$

- $a_{it} = k_{i,t+1}$ = choice of firm size for next period (and implicitly, entry and exit).

Profit Function (semi Reduced Form)

- If $k_{it} = 0$ (**inactive**): Profit $= 0$.

- For $k_{it} > 0$ (**active**):

$$\begin{aligned} \Pi_{it}(a) &= \theta^{FC}(k_{it}) + \theta^{VP}(k_{it})\ d_t + \theta^{COM}(k_{it})\ g\left(\sum_{j \neq i} a_{jt}\right) \\ &+ \sum_{k=0}^{3} 1\{k_{it} = k\}\ \theta^{AC}(a, k) \end{aligned}$$

- $\theta^{COM}(.)$ captures **competition effects**.

- $\theta^{AC}(a, k)$ is the **cost of adjusting firm size** from k to a.

  - When $k = 0$ & $a >= 0$, these are entry costs.

- Normalization: $\theta^{AC}(0, k > 0) = 0$, **zero scrap value or exit costs**.

Estimation: Basics

- Discount factor β is fixed at 0.95.
- Estimation method: Two-step PML estimator.
- County fixed-effects (FE) to deal with county time-invariant unobserved heterogeneity in Fixed Costs.

  - Note that there is an **incidental parameters problem** that makes the FE estimator inconsistent with fixed T.

  - Since $T = 24$ is relatively large, the bias of the FE estimator might be small. (???)

  - **Research idea**: Check for this using the Sufficient Statistics Conditional MLE in Aguirregabiria, Gu, & Luo (JOE, 2021).

Estimation Basics [2]

- To have parameters in dollar amount, C-W uses the information from interview to managers, and fixes entry cost to medium size to:

$$\theta(2,0) \;=\; \$\ 2\ \mathit{Million}$$

- Given this restriction it is possible to identify σ_ε, and given this parameter estimate, it is possible to obtain all the parameter estimates in dollar amounts.

- For the interpretation of the magnitude of some estimates, it is convenient to keep in mind that a plant's average annual sales is $3.4M.

Estimates of Structural Parameters (in thousands of dollars)

ESTIMATES FOR THE DYNAMIC MODEL OF ENTRY, EXIT, AND INVESTMENT[a]

		Coeff.	S.E.*
Fixed Cost	Small	−139	(6)
	Medium	−244	(10)
	Large	−285	(6)
Log Construction Employment	Small	20	(1)
	Medium	35	(2)
	Large	45	(1)
1st Competitor	Small	−48	(4)
	Medium	−58	(5)
	Large	−63	(6)
Log Competitors (Above 1)	Small	−17	(3)
	Medium	−44	(4)
	Large	−48	(3)

Structural Parameters: Adjustment Costs (in thousands of dollars)

Transition Costs		
Out → Small	−1002	(11)
Out → Medium†	*−2000*	(107)
Out → Large	−1771	(53)
Small → Medium	−332	(7)
Small, Past Medium → Medium	−772	(32)
Small, Past Large → Medium	−325	(8)
Small → Large	−1809	(73)
Small, Past Medium → Large	−608	(19)
Small, Past Large → Large	−343	(16)
Medium → Small	−107	(6)
Medium, Past Large → Small	−314	(6)
Medium → Large	101	(14)
Medium, Past Large → Large	−43	(7)
Large → Small	−254	(7)
Large → Medium	−403	(6)
Standard Deviation of Shock	133	

Estimation Results

- **Fixed cost:** $244,000 for a medium-sized. Increases with size but less than proportionally.

- **Competition effects:**
  - First competitor reduces profits by $58,000, for medium plant.
  - Doubling number of competitors reduces profits by $44,000 per year.

- **Switching costs.**
  - Entry costs ($2M for medium) are very large relative to the annual profit.
  - Increasing the size of a plant is also very costly: $1.8M from small to large.
  - It is cheaper to enter as a small plant and grow to a large plant in the next period (80% of plants enter as small plants).
  - There are also substantial cost of adjusting size down.

Counterfactuals: Effect of demand uncertainty

- Three experiments that **modify the stochastic process of demand**, and more precisely, **demand uncertainty**.
- **Experiment 1. 5 Years Smoothing.** Demand is constant over 5 years window (at its realized mean value over the 5 years). This reduces demand uncertainty.
- **Experiment 2. Constant demand.** Extreme version of the counterfactual. Completely eliminates uncertainty.
- **Experiment 3. Plants believe demand is constant,** though demand follows its true process in the data.
- Experiment 3 help us to distinguish the part of Experiment 2 that comes from beliefs and eliminating uncertainty – versus the change in the realization of demand.

Counterfactuals: Caveat

- Contrary to what is claimed in this paper, Fixed Cost, Entry Cost, and Exit Cost are not separately identified (see Aguirregabiria & Suzuki, 2014; Kalouptsidi, Scott, & Souza-Rodrigues, 2019, 2020).
- For this reason, as many other papers, the author "normalizes" the Exit Cost to zero.
- This normalization is innocuous for some counterfactuals (e.g., additive change in profit) but not for others.
- In particular, this normalization – if not true – generates inconsistent counterfactuals associated to a change in the transition of the state variables. This is exactly the type of counterfactual in this paper.
- These counterfactuals are correct only under the assumption that the scrap value is actually zero.

Demand uncertainty & Turnover

DEMAND SMOOTHING, TURNOVER, AND SIZE CHANGING

	Unsmoothed Demand ($\hat{D}^{\mu}$)	5 Years of Smoothing	Constant Demand	Firms Believe Demand is Constant
Turnover				
Entry Rate	2.7%	2.2%	2.2%	4.1%
Exit Rate	2.9%	2.0%	2.1%	4.5%
Change in Size Rate	20%	18%	17%	18%
Investment				
Sunk Entry Costs per Year (in Million $)	132	137	107	155
Size Changing Costs per Year (in Million $)	307	496	407	337
Total Plants	3643	5433	4264	3879

Demand uncertainty & Turnover [2]

- **Turnover:** Eliminating demand volatility has a modest effect on turnover. Most of turnover is due to firms' idiosyncratic shocks.

- **Turnover. Pure effect of Beliefs.** Beliefs of high uncertainty, reduce the response to demand shocks (generate inaction) and reduce turnover. [see last column].

- **Aggregate adjustment costs.** Two effects: (i) cost per firm; and (ii) change in the number of firms.

Demand uncertainty & Market Structure

DEMAND SMOOTHING AND INDUSTRY COMPOSITION

	Unsmoothed Demand	Constant Demand	5 Years of Smoothing
Total Plants	3645	4264	5433
Fixed Costs			
(per Period in Millions of $)	717	878	1109
Industry Composition			
Small Plants	54%	48%	49%
Medium Plants	23%	23%	24%
Big Plants	23%	29%	28%
Market Structure			
Markets With no Plants	5%	8%	1%
Markets With 1 Plant	43%	36%	25%
Market With 2 Plants	28%	24%	29%
Markets With More Than 2 Plants	25%	32%	46%

Demand uncertainty & Market Structure

- **Number of plants:** Reducing demand uncertainty increases importantly the number of plants in markets.

- **Size distribution.** Small changes. A small increase in the share of large plants.

- This result is generated by the **level of irreversibility in the different investment decisions**.
  - Sunk entry costs are very sizeable: reducing uncertainty has a large effect on entry.
  - The irreversibility of investments to grow (decline) in size are small.

Demand uncertainty, Profits, and Welfare

WELFARE EFFECTS OF DEMAND-SMOOTHING POLICIES[a]

Change in Net Present Value of	
Consumer Surplus	$860 Million
Producer Surplus for Incumbents	–$609 Million
Producer Surplus for Potential Entrants	–$36 Billion

[a]Numbers in this table refer to the difference in the net present value of surplus (using a 5% discount rate) between five years of smoothing and unsmoothed demand, averaged between 25 and 50 years after the policies were put into place, using 1976 as an initial state.

Demand uncertainty, Profits, and Welfare

- Reducing demand uncertainty increases the number of plants, reduces price, and has a positive effect of consumer surplus.
- The effect of uncertainty on firm value is ambiguous: it can be positive or negative, depending on whether the value function is concave or convex in demand.
- In this application, the value function turns out to be convex in demand such that reducing uncertainty reduces firms' value.

2. Time to Build and Fluctuations in Bulk Shipping

Kalouptsidi (2014) - Outline

1. Motivation
2. Some features of the Bulk Shipping industry
3. Data
4. Model
5. Estimation
6. Counterfactuals

Motivation

- In many industries, adjustment costs in capital investment take the form of **time to build**.
- Airlines or shipping firms face **lags of several years** between the order and the delivery of an aircraft / ship.
- Time to build, together with demand uncertainty, can generate inaction in investment as well as substantial deviations between optimal and actual capital stocks.
- Almost no micro empirical studies measuring the lags of time-to-build and its effects.

Bulk Shipping vessels

Bulk Shipping vessels

- Designed to carry a homogeneous unpacked dry or liquid cargo; mostly raw materials, e.g. , iron, steel, coal, grain, sugar.
- The entire cargo usually belongs to one shipper [in contrast to Containers shipping vessels].
- Operate like taxis: no scheduled itineraries, but individual contracts.
- Shipping services are largely perceived as homogeneous.

Some features of Bulk Shipping industry

- **Entry** occurs when shipowner buys a new ship from a shipyard.
- Building new ships is characterized by **significant construction lags**.
- Because shipyards have binding capacity, the average **time to build (TTB) is endogenous and varies over time**.

  - e.g., it increased from 6 quarters in 2001 to 12 quarters in 2008.

  - This endogeneity of TTB has not been recognized in previous studies.
- **Exit** occurs when shipowner scraps its ship.
- Volatility in shipping demand combined with the inelastic supply leads to volatile shipping prices

Volatility in shipping prices

FIGURE 3. THE BALTIC DRY INDEX

Model: State variables

- Within the class of dynamic games that we have seen in class.
- A firm is a shipowner. The **state variables** are:

  - The age of the own ship: $k_{it} \in \{0, 1, ..., K\}$

  - Age distribution of all the ships: $\mathbf{s}_t \in \{s_t^0, s_t^1, ..., s_t^K\}$
  where s_t^k = number of ships with age k.

  - Backlog of orders to (future deliveries from) shipyards:
  $\mathbf{b}_t \in \{b_t^1, b_t^2, ..., b_t^T\}$,

  where b_t^q = number of ships to be delivered at period $t + q$.

  - Aggregate demand of shipping services: d_t

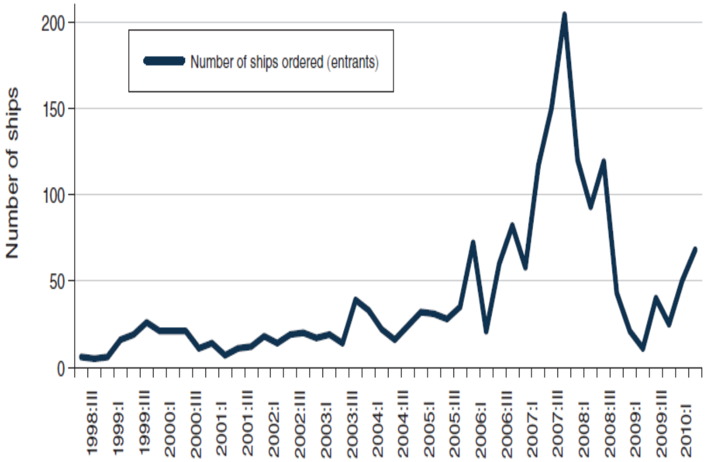
Model: Profit function

- **Flow profit** (without entry or exit costs) of a ship age k: $\pi(k, \mathbf{s}_t, d_t)$.
- **Exit value**: $\theta^{EX}(k) + \phi$, where ϕ private information shock.
- **Entry cost**: All potential entrants have the same entry cost: $\kappa(S_t^1, S_t^2, S_t^3, B_t, d_t)$.
- **Time to build**: All the new entrants at time t receive the same time to build: $T_t = T(S_t^1, S_t^2, S_t^3, B_t, d_t)$.
- In these functions:
  $S_t^1 = \#$ young competitors; $S_t^3 = \#$ mid-age competitors; $S_t^3 = \#$ old competitors.
  $B_t =$ Total Backlog $= \sum_{q+1}^{T} b_t^q$

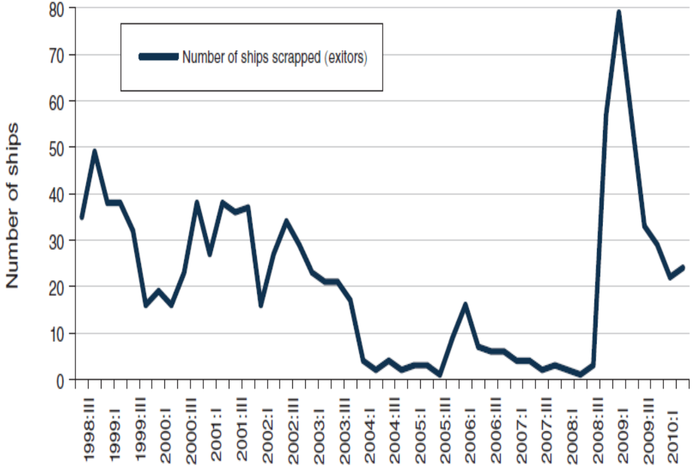
Data (Quarterly)

- **Quarterly time series of ships**. Fleet, New deliveries, and Demolitions. **For number of ships and age distribution**
- **Shipping voyage contracts.** Date of transaction; name and size of the ship; ship's price per trip. [January 2001 and June 2010]. **For prices and quantities of ship services.**
- **World secondhand ship sale transactions.** Date of transaction; name, age, and size of the ship sold; seller and buyer; price. [August 1998 to June 2010]. **For estimating value of a ship.**
- **Ship orderbook** All ships under construction and delivery date. [2001 to 2010] **For backlogs and time to build.**

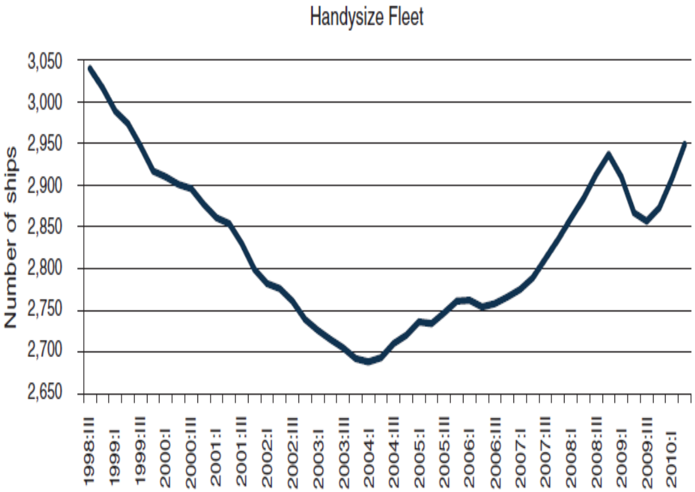
New entrants



Exits


Number of ships scrapped (exitors)
Number of ships
80
70
60
50
40
30
20
10
0
1998:III
1999:I
1999:III
2000:I
2000:III
2001:I
2001:III
2002:I
2002:III
2003:I
2003:III
2004:I
2004:III
2005:I
2005:III
2006:I
2006:III
2007:I
2007:III
2008:I
2008:III
2009:I
2009:III
2010:I

Incumbents


Handysize Fleet
Number of ships
3,050
3,000
2,950
2,900
2,850
2,800
2,750
2,700
2,650
1998:III
1999:I
1999:III
2000:I
2000:III
2001:I
2001:III
2002:I
2002:III
2003:I
2003:III
2004:I
2004:III
2005:I
2005:III
2006:I
2006:III
2007:I
2007:III
2008:I
2008:III
2009:I
2009:III
2010:I

Estimation Approach

- The econometric approach in this paper contains an interesting methodological innovation.
- On the one hand, it applies two-step CCP methods to estimate some parameters of the model – nothing new here.
- Interestingly, it also uses **data on tansaction prices of ships in the second hand market**.
- Under the assumption that the transaction price represents the value of the ship, MK uses these data to avoid the computation of (some) present values.
- Assumptions: ships are homogeneous (per size and age); no informational frictions or transactions costs in the second hand market. Then, the **secondhand transaction price must equal the value of the ship**.

Estimated Demand Function (Isoelastic)

TABLE 5—INVERSE DEMAND CURVE FOR FREIGHT TRANSPORT: IV REGRESSION RESULTS

	First stage, dep. variable Q_t		Second stage, dep. variable P_t	
	Parameter	SE	Parameter	SE
const	2.01	(20)	−7.601	(23.8)
WIP	−5.05	(3.4)*	9.501	(4.51)**
agr raw mat *P*	1.291	(0.97)*	2.969	(1.32)**
mineral *P*	0.394	(0.57)	−1.658	(0.565)**
food *P*	−0.548	(0.715)	−0.346	(0.702)
China steel	0.365	(0.716)	1.534	(0.592)**
Handymax	−2.03	(2.12)	−4.705	(1.324)**
fleet	0.0013	(0.0014)		(0.597)
mean age fl	0.287	(0.150)**		
std age fl	0.5823	(0.335)**		
$\widehat{Q}_t$			−0.162	

**Significant at the 5 percent level

Time to Build Estimates

TABLE 6—TIME TO BUILD REGRESSION ESTIMATES

	Constant	S^1	S^2	S^3	B	d
Parameters	2.536	−0.00082	−0.00063	0.00011	1.93e − 005	0.0303
Standard errors	(1.266)	(0.00058)	(0.00036)	(0.00036)	(8.3e − 005)	(0.019)

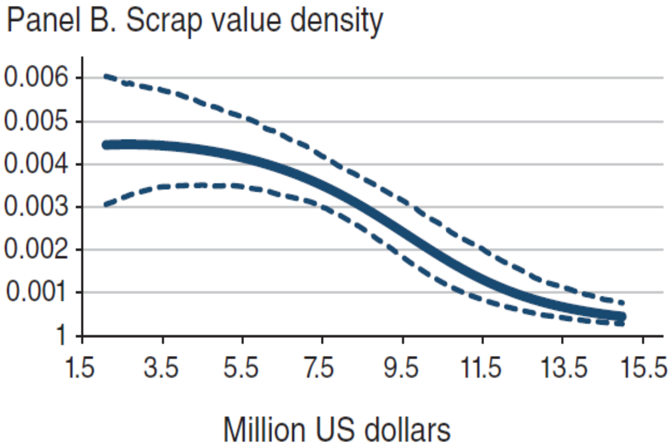
Notes: Standard errors based on 500 bootstrap samples. Coefficients joint significant at the 0.01 level.

Entry and Exit Estimates

TABLE 8—ENTRY AND EXIT REGRESSION ESTIMATES

	Constant	S^1	S^2	S^3	d
Entry					
Parameters	−8.425	−0.0024	−0.00045		0.934
Standard errors	(4.90)	(0.0025)	(0.00075)		(0.244)**
Exit					
Parameters	22.728	0.0073	0.00093	0.00104	−1.859
Standard errors	(4.89)**	(0.0016)**	(0.00092)	(0.0008)	(0.242)**

Estimation of Scrap Value Distribution



Observed vs. Predicted Time to Build

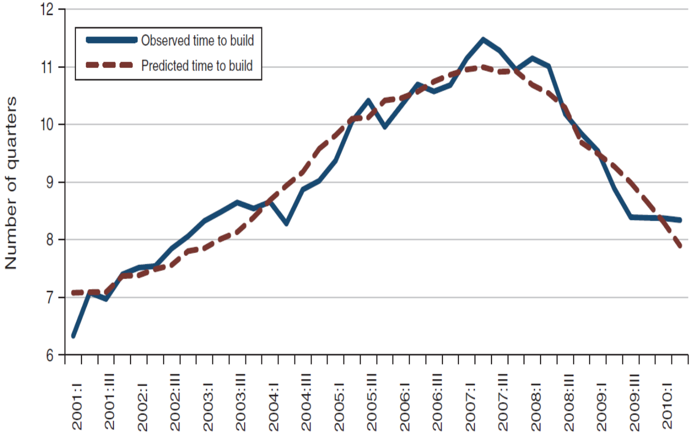
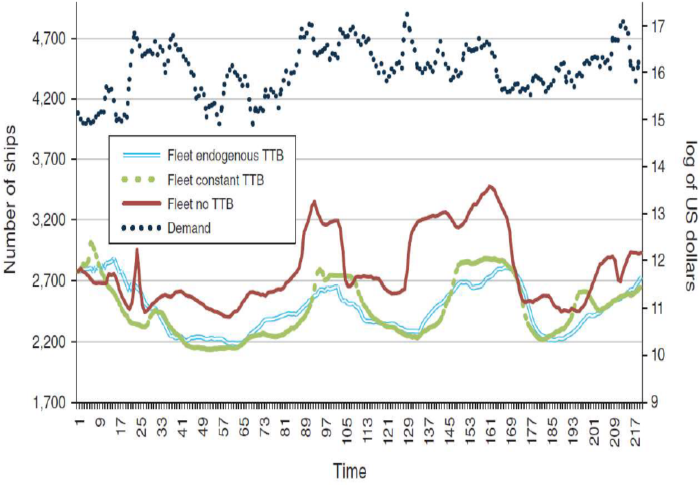


FIGURE 8. AVERAGE OBSERVED AND ESTIMATED TIME TO BUILD

Counterfactuals: Main empirical results

- Investment volatility is significantly higher as time to build declines.
- The fleet is 45 percent more volatile under constant time to build and twice more volatile under no time to build.
- Entry is twice more volatile under constant time to build and seven times more volatile in the absence of time to build.
- The fleet is larger by about 15 percent in the absence of time to build.

Counterfactuals: Time to Build (in sample)



Counterfactuals: Time to Build (long run)