Industrial Policy Implementation: Empirical Evidence from China's Shipbuilding Industry

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August 2024

IP in Action

- Industrial policy widely used in both developed and developing countries:
  - Japan in the 50-60s (Johnson 1982, Ito 1992);
  - South Korea and Taiwan in the 60-70s (Amsden 1989, Lane 2018);
  - China, India, Brazil, Mexico, etc. (Peres, 2013, Stiglitz and Lin 2013)
  - Lately Europe (including Germany and France) (Economist 2019)
- Rodrik (2010): *"The real question about industrial policy is not whether it should be practiced, but how"*

Challenges in Implementing IP

- Implementing IP in practice is a complicated task
- A large number of policy instruments
  - subsidies on output
  - provision of loans at below-market interest rates
  - preferential tax policies
  - tariff and nontariff barriers
- Many relevant considerations:
  - Timing and duration of policy intervention
  - Discriminatory or not (preference toward small or large firms)

An Example: Shipbuilding

- China's shipbuilding industry provides a clear example
- Dubbed a pillar industry in 11th (2006-2010) and 12th (2011-2015) FYP
- China overtook Japan and SK in a few years, but industry highly fragmented
- Financial crisis and plummeting ship prices forced policy changes:
  - Entry moratorium
  - Support prioritized to existing firms
  - White List

This Paper

- Much of the literature focuses on whether IP should be implemented and which sector
- We examine the IP design and implementation within a sector, as well as policies' long-term implications, featuring
  - Real business cycles and firm dynamics
  - A variety of policy instruments
  - Rich firm heterogeneity and market power
  - Firm decisions: production, investment, entry and exit
- We ask the following questions:
  - How did China's policy affect the global industry?
  - What is the relative performance of different policy instruments?
  - Towards optimal policy design

Related Literature

- Industrial Policy
  - Recent studies: Greenwald and Stiglitz (2013), Aghion et al (2015), Kalouptsidi (2018), Lane (2019), Liu (2019); Strategic trade policy: Grossman (1990), Brander (1995), Baldwin and Krugman (1987); Earlier studies: Baldwin & Krugman (1986), Head (1994), Hansen et al (2003)
- Industry Dynamics
  - Hopenhayn (1992), Ericson and Pakes (1995), Benkard (2004), Ryan (2012), Bajari, Benkard and Levin (2008), Kalouptsidi(2014), Barwick and Pathak (2015)
- Studies on China's industrial development and policy interventions:
  - Consolidation policies (Rubens,2021), R&D incentives (Chen et al., 2021), value-added tax reforms (Liu and Mao, 2019; Bai and Liu, 2019)
- Shipping and Shipbuilding industry
  - Thompson (2001), Greenwood and Hanson (2015), Kalouptsidi (2014, 2020), Jeon (2018)

Outline

1. Industry Description and Facts
2. Model
3. Data and Empirical Strategy
4. Estimation results
5. Counterfactual analysis
6. Conclusion

(Chinese) Shipbuilding

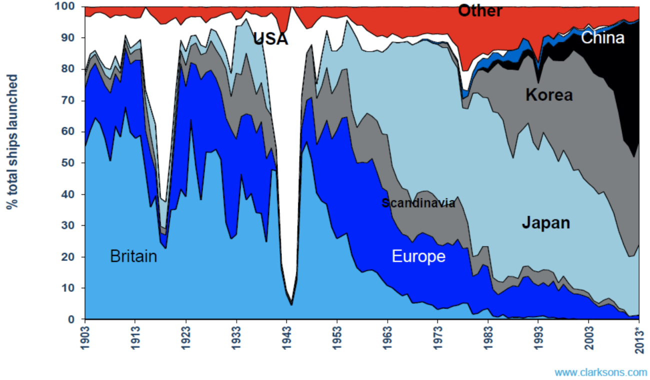
Industry Description

- Bulk Cargos
  - homogeneous, unpacked, for individual shippers on non-scheduled routes
  - **Dry Bulk**: raw materials (iron ore, grain, coal, steel, etc.)
  - **Tankers**: crude oil, oil products, chemicals
  - 72% of world seaborne trade in tons
- Containerized cargos
  - items from different shippers in regular port-to-port itineraries
  - **Containerships**
- Unconcentrated industries and/or active leasing markets
- Bulk, tanker, and container accounted for 90% of world orders in tons from 1998-2013

Commercial Ships

- Commercial ships are the largest factory produced products

History of Shipbuilding



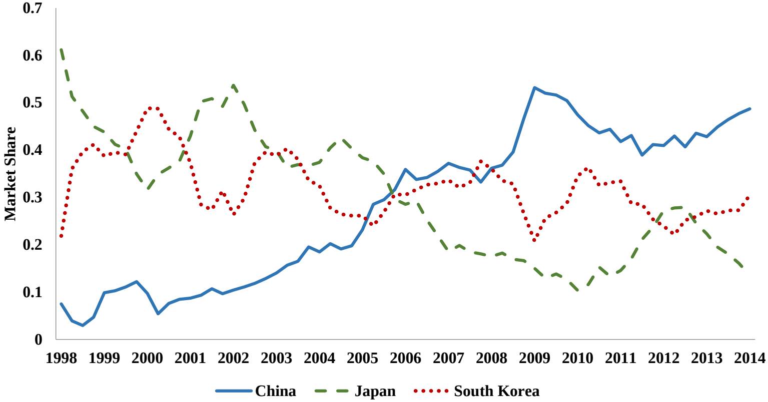
- Shipbuilding a classic target and one of major subsidy recipients
- 1850s Britain; 1950s Japan; 1970s S. Korea; 2000s China

Major Policies in China

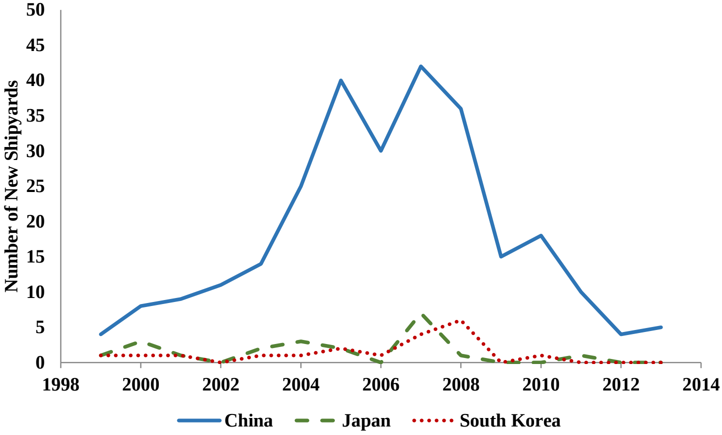
Table: Shipbuilding National Industrial Policies

Year	Shipbuilding National Industrial Policies	Plan Period
2003	National Marine Economic Development Plan	2001-2010
2006	The 11th Five-Year Plan for National Economic and Social Development	2006-2010
2006	The Medium and Long Term Development Plan of Shipbuilding Industry	2006-2015
2007	The 11th Five-Year Plan for the Development of Shipbuilding Industry	2006-2010
2007	The 11th Five-Year Plan for the Development of Shipbuilding Technology	2006-2010
2007	11th Five-Year Plan for the Development of Ship Equipment Industry	2006-2010
2007	Guideline for Comprehensive Establishment of Modern Shipbuilding (2006-2010)	2006-2010
2007	Shipbuilding Operation Standards	2007-
2009	Plan on the Adjusting and Revitalizing the Shipbuilding Industry	2009-2011
2010	The 12th Five-Year Plan for National Economic and Social Development	2011-2015
2012	The 12th Five-Year Plan for the Development of the Shipbuilding Industry	2011-2015
2013	Plan on Accelerating Structural Adjustment and Promoting Transformation and Upgrading of the Shipbuilding Industry	2013-2015
2013	Shipbuilding Industry Standard and Conditions	2013-

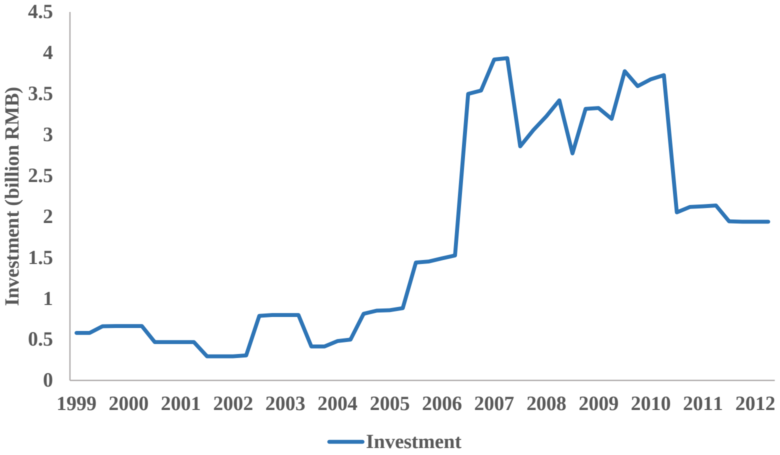
China's Market Share Expansion



Entry of New Shipyards



Investment



Capital Expansion
Capital Expansion of Existing Firms

- Capacity expansion is universal across firm age, ownership status, and geographical area

Model

Model Overview

- Agents:
  - Chinese firms
  - Foreign firms (Japanese and S. Korean shipyards)
- Decisions:
  - Capital accumulation; entry and exit (dynamic)
  - Production (static)
- Products: M ship types
  - Segregated markets
  - Ships homogeneous within a type

Chinese Industrial Policy

- Chinese central and regional government policies (T_t) may provide:
  - Production subsidies that lower $C(q_{jt})$
    - input subsidy, export credits, preferential buyer financing
  - Capital subsidies that lower $C^I(i_{jt})$
    - low-interest credit, tax credits for accelerated capital depreciation
  - Entry subsidies that lower κ_{jt}
    - cheap land, simpler registration procedure
- A simple model of T_t:
  - Two policy shocks (2006 and 2009)
  - They arrive unexpectedly and are considered permanent
- The transition process of payoff relevant variables (including prices) are assumed to satisfy the Markovian property pre- and post- policy intervention.

Model

- Time is discrete with an infinite horizon. J shipyards. In each period,
  - Incumbents draw productivity, choose quantities, and receive payoffs
  - Existing firms receive a random scrap value and decide whether to exit
  - Continuing firms draw an investment cost and make investment decisions
  - Each potential entrant draws an entry cost and decides whether to enter
  - Entry, exit, and investment decisions are implemented
- Yard j is characterized by state s_{jt} including all payoff relevant variables:
  - country / region, ownership status, backlog, capital
  - ship market prices, input prices (steel)
  - government policies

Model: Static Decisions

- Market demand for ships (omitting subscript on ship type):

$$Q_t^d = d_t - \eta P_t$$

  - d_t is "market size", determined by world demand shifters, such as freight rates, commodity prices, total fleet

- Shipyards compete in Cournot and solve (s_{jt} denotes cost shifters):

$$\max_{q \geq 0} P_t q - C\left(q, s_{jt}\right)$$

  which leads to profit

$$\pi\left(P_t, s_{jt}, q^*(P_t, s_{jt})\right)$$

- The market clears when total supply $Q_t = \sum_j q^*\left(P_t, s_{jt}\right)$ equals demand $Q_t^d = d_t - \eta P_t$
  - Equilibrium ship price $P\left(s_t, d_t\right)$

Model: Dynamic Decisions

- Each incumbent receives a random scrap value ϕ_{jt} and decides whether to exit
- Shipyard j with capital k_{jt} invests i_{jt} to accumulate capital:

$$k_{jt+1} = (1-\delta)k_{jt} + i_{jt}$$

- Bellman equation (s_{jt} includes all state variables):

$$V(s_{jt}, \phi_{jt}) = \pi(s_{jt}) + \max_{\chi_{jt}} \left\{ \begin{array}{c} \phi_{jt}, \\ \max_{i_{jt}} \left(-C^I(i_{jt}, s_{jt}) + \beta E\left[V(s_{jt+1}) | s_{jt}, i_{jt}\right]\right) \end{array} \right.$$

- Investment cost is $C^I(i_{jt}, s_{jt})$, inclusive of adjustment costs
- Optimal policies:

$$\chi^*(s_{jt}, \phi_{jt}), i^*(s_{jt}), \text{ and similarly } \chi^{e*}(s_{jt}, \kappa_{jt})$$

Bellman for entry

Data

Data

- Clarksons (1998-2014) :
  - Quarterly level data on prices P_{mt}
  - Orders received by type for each shipyard q_{mjt}
  - Characteristics for Japan and S. Korea shipyards
- Annual survey of Chinese Manufacturing firms (1998-2013)
- Official documents on industrial policies (1998-2013)

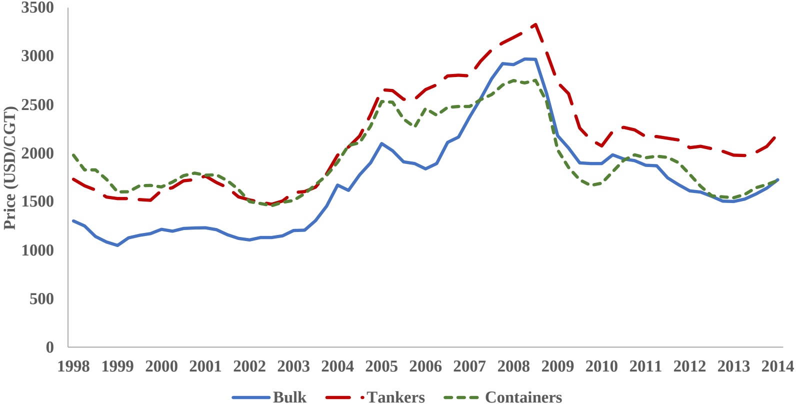
Summary Statistics

Table: Summary statistics by firm-quarter

Variable	Obs	Mean	S.D.	Min	Max
All Obs.					
Bulk orders (1000 CGT)	10,101	17.1	51.9	0.0	968.2
Tanker orders (1000 CGT)	10,583	9.6	46.2	0.0	1119.0
Container orders (1000 CGT)	4,813	18.9	93.9	0.0	1644.1
Bulk backlog (1000 CGT)	10,101	171.4	329.3	0.0	2830.5
Tanker backlog (1000 CGT)	10,583	98.5	315.1	0.0	3840.8
Container backlog (1000 CGT)	4,813	206.6	670.5	0.0	7362.8
Investment (mill RMB)	4,386	18.5	88.9	-240.5	1,770.7
Capital (mill RMB)	6,157	392.0	806.9	0.3	8,203.3
Obs. With Positive Orders					
Bulk orders (1000 CGT)	2,316	74.6	86.5	3.9	968.2
Tanker orders (1000 CGT)	1,436	70.4	107.1	0.05	1,119.0
Container orders (1000 CGT)	625	145.3	222.7	2.3	1,644.1

- Quantity in 1000 Compensated Gross Tonnage (CGT)
- Investment and Capital in mill RMB

Ship Prices



3500
3000
2500
2000
1500
1000
500
0
Price (USD/CGT)
1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Bulk
Tankers
Containers

Estimation

State Variables

- Individual specific states:
  - Capital k_{jt}, backlog (economies of scale and learning)
  - Region, size, ownership status, etc.
- Aggregate states:
  - Industrial policy/subsidies T_t
  - Prices for different ship types P_{mt}, steel price (cost of producing ships)
    - Ship prices and their transition process are 'sufficient' for firms to predict their future profitability
  - Aggregate ship demand shifters d_t (for counter-factual analysis)

Empirical Estimation

- Primitives to recover:
  - Shipyard production costs:
    $$C\left(q_{jt}, T_t\right)$$
  - Investment cost:
    $$C^I\left(i_{jt}; T_t\right)$$
  - Distribution of entry and exit costs:
    $$\phi_{jt}, \kappa_{jt}(T_t)$$
  - Ship demand curves (for counter-factual analysis):
    $$P_m\left(d_{mt}, Q^d_{mt}\right)$$

Estimate Cost Function

- The marginal cost of producing q_{jmt} equals:

$$MC(q_{jmt}) = z_{jmt}\beta_m + \delta_m q_{jmt} + \omega_{jmt}$$

  - z_{jmt}: capital, backlog, age, province, size, ownership, and subsidies
  - Capital and backlog capture economies of scale and learning
  - ω_{jmt}: a cost (productivity) shock
  - Firms compete in quantities (Cournot)
  - Cost estimates similar with dynamic production (Kalouptsidi 2018)
    - Production expansion too big to be explained by dynamic considerations
  - Firms equate $MC(q_{jmt})$ with $MR(q_{jmt})$

Estimate Cost Function

- There are J_t^c Chinese firms and J_t^f foreign firms (in Japan and S. Korea)
  - foreign firms' marginal cost function similar $MC_f\left(q_{jmt}\right)$
- The total production cost equals:

$$C(q_{jmt}) = \int_0^{q_{jmt}} MC(q)dq + c_0$$

- c_0: fixed cost of production
  - incurred every period;
  - ignored in many studies; estimated from accounting data
- No participation (production $q_{mjt} = 0$) if productivity ω_{mjt} too low
  - orders are lumpy (zero orders are common)

Estimate Cost Function

- Assume ω_{jmt} has a normal distribution $N(0, \sigma_\omega^2)$
  - Can handle serially correlated productivity shocks ω_{jmt} (Robinson 1982)
- The sample likelihood:

$$L = \prod_{j,t,m} \prod_{q_{jmt}=0} Pr(q_{jmt} = 0 | s_{jt}; \theta^c) \prod_{q_{jmt}>0} f_q(q_{jmt} | s_{jt}; \theta^c)$$

Production Cost Estimates

	Bulk		Tanker		Container	
Type-specific	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
MC (thousand RMB / CGT)						
δ_m	7.29	7.59	14.13	5.10	10.58	5.01
σ_ω	9.58	8.93	16.27	6.91	13.77	5.14
Constant (1000 RMB/CGT)	20.37	14.05	39.71	8.78	34.92	7.27
Steel Price (1000 RMB/Ton)	1.68	6.85	1.14	2.83	0.66	1.50
Capital (bill RMB)	-2.67	-2.85	-2.89	-1.74	-2.44	-1.93
Capital^2	0.20	0.80	0.07	0.24	0.06	0.28
Backlog	-1.80	-5.03	-5.02	-4.97	-3.30	-3.19
Backlog^2	0.08	3.94	0.26	3.44	0.20	1.94
Backlog of Other Types	0.13	0.86	0.38	1.57	0.53	2.61
Common						
2006-2008	-2.10	-3.01				
2009+	-1.22	-1.78				
Large firms	-4.32	-6.54				
Jiangsu	-2.96	-4.61				
Zhejiang	-1.62	-2.80				
Liaoning	-2.10	-2.01				
CSSC/CSIC	-0.86	-1.17				
Private	0.16	0.30				
Foreign JV	-0.86	-1.41				
Age	0.21	3.22				
N	4886		4977		2504	

Cost Function Estimates

- δ suggests firms are responsive to prices:
  - Bulk / tanker / container production goes up by 22% / 27% / 20% with a 10% price increase
  - Convex cost: at $\bar{q}$, $\delta * q$ accounts for 24-58% of a firm's marginal cost
- Larger capital associated with lower cost of production
  - Setting capital to 0 reduces profit by 38%
- Marginal cost decreases with backlog initially (economies of scale) and then increases (capacity constraints)
  - Increasing backlog by 100k CGT reduces marginal cost by 13-30%

Cost Function Estimates

- Production subsidy from 2006 to 2008 equals to 14-18% of the price
- MC for firms in Jiangsu/Liaoning/Zhejiang is lower by 20-26%, 14-18%, and 11-14%, respectively
- Fixed cost c_0 sizable (12% of profits)
- Results robust across alternative specifications
  - pooling across countries
  - drop new shipyards
  - firm- and industry-level learning by doing

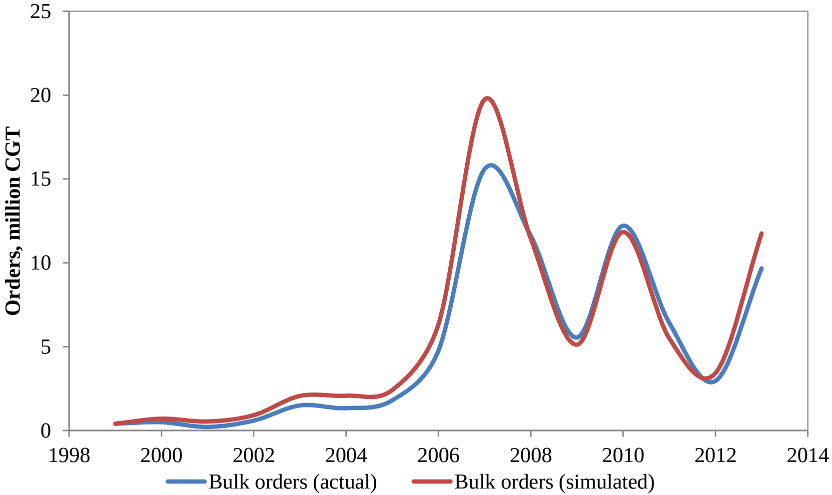
Robustness

Spillover

	Bulk		Tanker		Container	
Type-specific	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Allow for within-firm learning						
Capital (bill RMB)	-2.16	-1.85	-2.29	-1.43	-1.22	-1.12
Backlog	-1.67	-4.78	-5.30	-5.09	-1.13	-1.40
Cumulative Q	0.08	4.12	0.10	5.22	0.02	3.60
Allow for within-firm and industry-wide learning						
Capital (bill RMB)	-2.48	-2.14	-4.80	-1.66	-2.81	-1.26
Backlog	-1.60	-4.14	-9.24	-3.67	-2.47	-1.15
Cumulative Q	0.09	4.49	0.18	3.93	0.03	2.58
Cumulative Q, China	-0.02	-0.79	0.39	2.10	0.68	1.61

- Limited evidence for industry-wide spillovers

Goodness of Fit for Bulk Orders



▸ Tankers and containers

Empirical Estimation

- Primitives to recover:
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  - Investment cost:
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  - Distribution of entry and exit costs:
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  - Ship demand curves (for counter-factual analysis):
    $$P_m\left(d_{mt}, Q^d_{mt}\right)$$

Bellman Equation

- The Bellman equation for incumbents is:

$$V(s_{jt}, \phi_{jt}) = \pi_{jt} + \max_{\chi_{jt}} \{\phi_{jt}, CV(s_{jt})\}$$

- Assume $\phi_{jt} \sim F_{\phi}(\sigma)$ (exponential), ex-ante value fn is:

$$\begin{aligned} V(s_{jt}) &= \pi_{jt} + p^x \sigma + CV(s_{jt}) \\ CV(s_{jt}) &= E_{\nu_{jt}} \{ \max_{i_{jt}} [-C^I(i_{jt}, \nu_{jt}) + \beta E[V(s_{jt+1}) | s_{jt}, i_{jt}]] \} \end{aligned}$$

- Cost of investment:

$$C^I(i_{jt}, \nu_{jt}) = c_1 i_{jt} + c_2 \nu_{jt} i_{jt} + c_3 i_{jt}^2 + c_4 T_t i_{jt}$$

  - Random investment shocks ν_{jt}
  - Quadratic adjustment costs (c_3).
  - Investment subsidy (c_4)
  - Other types of adjustment costs ($\frac{i^2}{k}$, random fixed costs, irreversibility) insignificant

- Challenges with evaluating the ex-ante value fn:

$$\begin{aligned} V(s_{jt}) &= \pi_{jt} + p^x \sigma + CV(s_{jt}) \\ CV(s_{jt}) &= E_{\nu_{jt}}\{ \max_{i_{jt}} [-C^I(i_{jt}, \nu_{jt}) + \beta E[V(s_{jt+1}) | s_{jt}, i_{jt}]]\} \end{aligned}$$

- Optimal investment $i^*(\cdot)_{jt}$ depends on unobs shock ν_{jt} in addition to s_{jt}
- Solving $i^*(s_{jt}, \nu_{jt})$ directly requires knowledge of $E[V(s_{jt+1}) | s_{jt}, i_{jt}]]$
- Evaluating $CV(s_{jt})$ requires integrating out ν_{jt} and plugging in $i^*(s_{jt}, \nu_{jt})$

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CV Calculation

- (Ex post) continuation value fn:

$$CV(s_{jt};\nu_{jt}) = \max_{i_{jt}} \big(-C^I(i_{jt},\nu_{jt}) + \beta E[\ V(s_{jt+1}|s_{jt},i_{jt})\ ]\ \big)$$

- Optimal investment $i(s_{jt},\nu_{jt})$ is a complicated object
- Assume $i(s_{jt},\nu_{jt})$ monotonically increases in ν_{jt}
  - firms with favorable shocks invest more, everything else equal
  - Conditioning on s_{jt}, jth quantile of ν_{jt} corresponds to jth quantile of i_{jt}
- $F(i_{it}|s_{jt})$: dist. of i_{jt} conditional on s_{jt}. Assume $\nu_{jt} \sim G$
- Under monotonicity, the investment policy function is (BBL):

$$i_{jt} = F^{-1}[G(v|s_{jt})]$$

- Why is this result useful?

Value Function Approximation

- Value function is approximated with B-spline basis functions:

$$V(s_{jt};\vec{\gamma}) = \sum_{l=1}^{L} \gamma_l u_l(s_{jt})$$

  - The value fn inherits the shape of the payoff fn (π_{jt})
  - B-spline can flexibly approximate smooth functions

- The Bellman equation is:

$$V(s_{jt};\vec{\gamma}) = \pi_{jt} + p^x\sigma + CV(s_{jt};\vec{\gamma})$$

$$CV(s_{jt};\vec{\gamma}) = E_{\nu_{jt}}\big(- C^I(i^*_{jt}, \nu_{jt}) + \beta E[V(s_{jt+1};\vec{\gamma})|s_{jt}, i^*_{jt}]\big)$$

- Choose $\vec{\gamma}$ such that the Bellman equation is satisfied
- Once we 'know' the value function, we can derive the model's predictions to take to data

Investment Likelihood

- Denote $i^*_{jt} = i(s_{jt}, \nu_{jt})$ as the optimal investment, which is given by

$$\frac{\partial C^I(i^*_{jt}, \nu_{jt})}{\partial i_{jt}} = \frac{\partial \beta E[\ V(s_{jt+1}; \vec{\gamma})|s_{jt}, i^*_{jt}\ ]}{\partial i_{jt}}$$

  - Investment is random, driven by ν_{jt}
  - Density function of i_{jt} :

$$f_i(i_{jt}) = \frac{f_v(\nu_{jt})}{|i'(v_{jt})|}$$

Constrained MLE

- Probability of exiting ($\chi_{jt} = 1$ if firm j exits):

$$Pr(\chi_{jt} = 1) = Pr(\phi_{jt} > CV(s_{jt}; \vec{\gamma}, \theta^I))$$

- Maximize sample MLE of exits and investment:

$$L = \prod_{j,t} Pr(\chi_{jt} = 1)^{1[\chi_{jt}=1]} Pr(\chi_{jt} = 0)^{1[\chi_{jt}=0]} \prod_{j,t} f(i_{jt})$$

  subject to:

$$\vec{\gamma} = \arg\min \|V(s_{jt}; \vec{\gamma}) - \pi_{jt} - p^x \sigma - CV(s_{jt}; \vec{\gamma}, \theta^I)\|$$

  - σ: mean of the scrap value
  - θ^I: investment cost parameters

- Probability of entry similar (separate MLE estimation)

Entry

- Value of entry is 'known':

$$VE(s_{jt}) \equiv E_{K_0}\big(-C^I(K_0) + \beta E[V(s_{jt+1}|s_{jt}, K_0)] \ \big)$$

  - Entrant receives an initial capital stock K_0 that is drawn from the empirical distribution

- Entry cost κ_{jt} includes the cost of setting up a shipyard (getting permits, buying land, building docks, etc.)
- Probability of entry ($\chi^e_{jt} = 1$ if firm j enters):

$$Pr(\chi^e_{jt} = 1) = Pr[\kappa_{jt}(T_t) \leq VE(s_{jt})]$$

  - $\kappa_{jt}(T_t) \sim F_\kappa(\sigma)$ (exponential) differs across regions and policy regimes

- Maximize sample MLE of entry:

$$L^E = \prod_{j,t} Pr(\chi^e_{jt} = 1)^{1[\chi^e_{jt}=1]} Pr(\chi^e_{jt} = 0)^{1[\chi^e_{jt}=0]}$$

where we plug in $\hat{VE}(s_{jt})$

Practical Considerations

- The vector of state variable is high-dimensional (discretization impractical):
  - A large number of firms and many firm attributes
- Industry-level prices are "sufficient" statistics for future profitability
  - A behavioral assumption; analogous to 'oblivious equilibrium' (Weintraub et al 2008, 2017; Benkard et al 2015)
- A number of states enter costs linearly and is collapsed into an index: $\bar{s}_{jt} = -s_{jmt}\hat{\beta}_{sm}$
  - Higher $\bar{s}_{jt}$ indicates higher efficiency
- Expand the sample with unobserved states to help with the Bellman equation estimation
  - In spirit similar to the traditional approach of state discretization

Investment Cost Estimates

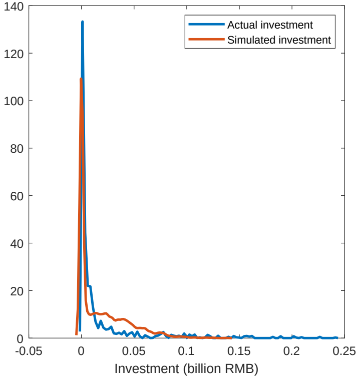
$$C^I(i_{jt}, \nu_{jt}) = c_1 i_{jt} + c_2 \nu_{jt} i_{jt} + c_3 i_{jt}^2 + c_4 T_t i_{jt}$$

Table: Investment Cost Estimates

	Coeff.	t-stat
c_1	1.00	
c_2	2.07	9.67
c_3	29.54	14.49
c_4 2006-08	-0.27	-1.70
c_4 Post 2009	-0.46	-3.27
N	4286	

- Standard errors from 500 block bootstrap simulations
- Importance of ν_{jt}

Goodness of Fit for Investment



- Quadratic adj. costs: 28% of investment costs; $> 50\%$ for large investments ($>$ 50mill)
- Proportion of investment costs subsidized high

Entry Cost Estimates

Table: Entry Cost Distribution (Mean), billion RMB

	κ_{pre}	κ_{06-08}	% of pre-06 cost	κ_{09+}	% of pre-06 costs
Jiangsu	86	31	36%	91	106%
Zhejiang	133	54	41%	264	199%
Liaoning	82	40	49%	-	-
Other	38	15	38%	61	160%

- $\kappa_{jt}(T_t)$ (exponentially distributed) differs across regions and policy regimes
- Subsidies during 06-08 reduced entry costs by 50-60%, robust to $\bar{N}^e$
- Entry moratorium in 2009 reflected in significant increase in entry costs

Goodness of Fit for Entry and Exit

Table: Model Fit for Entry

	Pre	2006-2008	2009+	Total
Actual entries	83	122	39	244
Simulated entries	65	132	28	225

- Mean entry cost paid per entrant is 2.3 bn RMB; close to accounting estimates.

Table: Model Fit for Exit

	1999-2005	2006+	Total
Actual exits	5	43	48
Simulated exits	9	32	41

- Mean of the scrap value distribution is 0.98 bill RMB, t-stat 12.3

Identification

- Magnitude of the industrial policies is identified through:
  - Comparison between China and other countries (Japan and S. Korea)
    - Integrated world demand, similar production technology
  - Comparison between policy period and non-policy period
    - Identify policy period through public official documents
  - Comparison across regions (Jiangsu, Zhejiang, and Guangdong vs. the rest of the country)
- Key insight: changes in entry/exit, investment, production that cannot be explained by observed factors

Empirical Estimation

- Primitives to recover:
  - Shipyard production costs:
    $$C\left(q_{jt}, T_t\right)$$
  - Investment cost:
    $$C^I(i_{jt}; T_t)$$
  - Distribution of entry and exit costs:
    $$\phi_{jt}, \kappa_{jt}(T_t)$$
  - Ship demand curves (for counter-factual analysis):
    $$P_m\left(d_{mt}, Q^d_{mt}\right)$$

Ship Demand Curves

- Ship Demand: demand from shipowners for cargo transportation
- Type-specific demand:

$$Q^d_{mt} = X^d_{mt}\beta + \eta P_{mt} + \varepsilon^d_{mt}$$

where

- Q^d_{mt} total tonnage of ship orders for type m in period t
- X^d_{mt} includes: freight rate, cargo shifters, backlog, fleet
- Instruments: world steel production, steel prices
- Aggregate backlog and fleet are proxies for dynamic factors that affect ship demand
- Noticeable changes in the shape of demand curve post 2006
- Other specifications: log-log

Ship Demand Estimates

Table: Ship Demand Estimates

Dependent variable:	(1) Orders	(2) Orders	(3) Orders	(4) Orders
Price (bulk)	-2.34***	-1.67***	-2.07***	-2.12***
	(0.77)	(0.64)	(0.69)	(0.75)
Price (tanker)	-2.66***	-1.46*	-1.80**	-1.76**
	(0.60)	(0.88)	(0.78)	(0.89)
Price (container)	-4.85***	-2.44***	-3.39***	-3.39***
	(0.91)	(0.85)	(1.01)	(0.99)
Price*Post2006	1.34***	1.00***	1.15***	1.34**
	(0.18)	(0.14)	(0.15)	(0.55)
Backlog (log)	0.34	-1.00***	-0.78**	-0.81**
	(0.25)	(0.33)	(0.38)	(0.37)
Freight Rate	Yes	Yes	Yes	Yes
Demand shifters		Yes	Yes	Yes
Trend			Yes	Yes
Trend*Post2006				Yes

- Ship demand becomes less elastic post-2006
  - Implied elasticities of 1.8 (bulk), 1.8 (tanker), and 3.4 (containerships) prior to 2006
  - Implied elasticities of 0.3 (bulk), 0.6 (tanker), and 1.6 (containerships) after 2006
- A large aggregate backlog leads to depressed demand
- We use this aggregate demand curve to simulate equilibrium prices in counter-factual

Summary

- A large number of individual and aggregate state variables s_t
- A combination of discrete choices (entry and exit) and continuous choice (investment) with unobserved shocks
- Recall the ex-ante value fn is:

$$\begin{aligned} V(s_{jt}) &= \pi_{jt} + \max_{\chi_{jt}} \{\phi_{jt}, CV(s_{jt})\} \\ CV(s_{jt}) &= E_{\nu_{jt}} \{ \max_{i_{jt}} [-C^I(i_{jt}, \nu_{jt}) + \beta E[V(s_{jt+1}) | s_{jt}, i_{jt}]] \} \end{aligned}$$

- Discretization and full solution method difficult if not infeasible
- Dimensionality reduction important
  - Ergodic states; exchangeability (symmetry assumptions);
  - Oblivious equilibrium;
  - Sufficient statistics: inclusive value in dynamic demand models;
  - A number of states enter costs linearly and is collapsed into an index: $\bar{s}_{jt} = -s_{jmt}\hat{\beta}_{sm}$

Summary

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Constructing the Value Function

- Full solution method and nested fixed point iteration;
  - Value Fn iteration vs. Policy fn iteration
- Two-step estimator and iterated two-step estimation (to reduce the notice in estimated CCP);
  - Rewrite continuation value function as a function of CCPs;
- Forward simulation (controlling for the noise in the policy function estimation important)
  - BBL, Dubois and Pakes (only discounted sum of future profit, no Bellman equation)
- Value function approximation

Value Fn Approximation

- Value function is approximated with basis functions:

$$V(s_{jt}; \vec{\gamma}) = \sum_{l=1}^{L} \gamma_l u_l(s_{jt})$$

  - The value fn inherits the shape of the payoff fn (π_{jt})
  - This paper uses B-spline, which can flexibly approximate smooth functions
  - Choose the basis fns that best approximate the payoff fn
- In addition to B-splines, there are other/better methods:
  - Lasso/ridge (linear methods)
  - Cubic Splines, Natural Splines, and Smooth Splines (nonlinear methods)
  - Neural networks

Neural Networks

- Neural Networks are highly flexible nonlinear models for prediction
- They work by first transforming x (or *input layer*) into hidden units, and finally using *hidden units* to produce an *output layer* $f(x)$

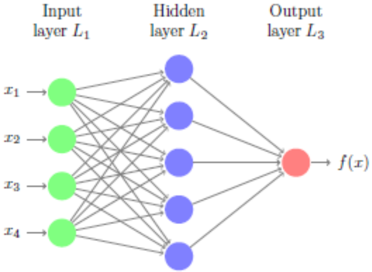

Figure 18.1 Neural network diagram with a single hidden layer. The hidden layer derives transformations of the inputs—nonlinear transformations of linear combinations—which are then used to model the output.

Neural Networks: Basic Elements

- Example: consider a one-layer network with $\dim x = 4$, five hidden units and one single output
- The hidden units are obtained via a nonlinear transformation of a linear index of inputs (sigmoid fn):

$$a_l = g\left(w_{l0}^{(1)} + \sum_{j=1}^{4} w_{lj}^{(1)} x_j\right)$$

  and the output is obtained w/ another transformation of hidden units (identify fn or softmax fn):

$$f\left(x\right) = h\left(w_{0}^{(2)} + \sum_{l=1}^{5} w_{l}^{(2)} a_l\right)$$

- Each hidden unit *(neuron)* a_l connected to inputs w/ *weights* $\left\{w_{lj}^{(2)}\right\}_{j=1}^{p}$

Evaluating Approximations

- How do we know whether the value fn approximation is "good enough"?
- The Bellman equation!

$$V(s_{jt};\vec{\gamma}) = \pi_{jt} + p^x\sigma + CV(s_{jt};\vec{\gamma})$$

$$CV(s_{jt};\vec{\gamma}) = E_{\nu_{jt}}\big(-C^I(i^*_{jt},\nu_{jt}) + \beta E[V(s_{jt+1};\vec{\gamma})|s_{jt},i^*_{jt}]\big)$$

- Need the average/max norm smaller than a tolerance level

$$\|V(s_{jt};\vec{\gamma}) - [\pi_{jt} + p^x\sigma + CV(s_{jt};\vec{\gamma})]\| \leq \epsilon$$

Evaluating Approximations

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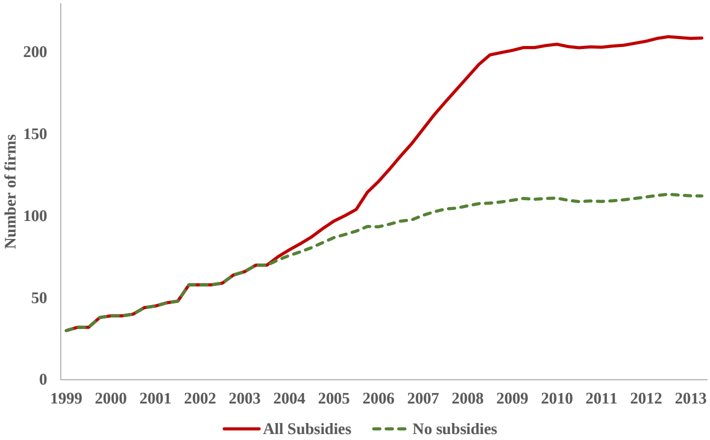
$$\|V(s_{jt};\vec{\gamma}) - [\pi_{jt} + p^x\sigma + CV(s_{jt};\vec{\gamma})]\| \leq \epsilon$$

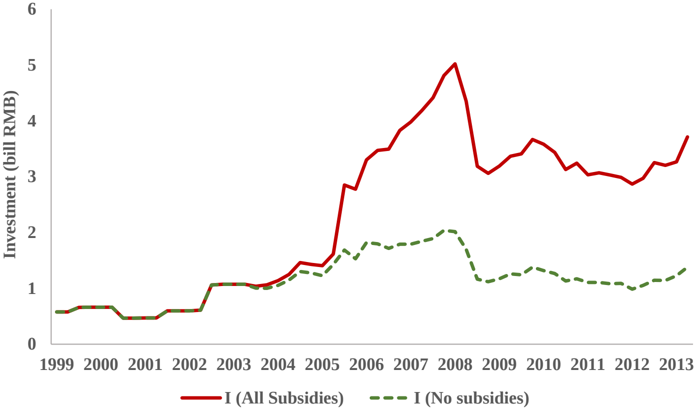
Evaluation of China's Industrial Policy

Number of Firms



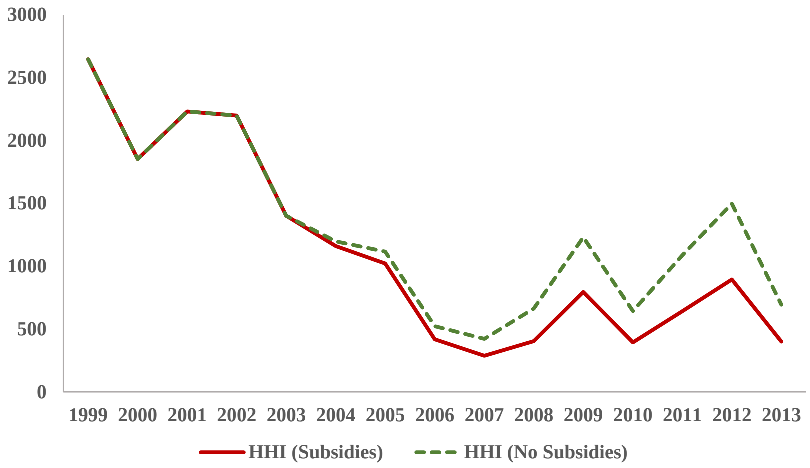
- From 2006-2013, 143 firms enter with subsidies vs. 64 without
- Subsidies depress number of exits (38 vs. 43) and change distribution of exitting firms: fewer incumbents exit but more entrants exit in downturn

Investment



- Total investment during 2006-2013 is 80 bill RMB with subsidies vs. 33 bill RMB without subsidies

Concentration



- HHI is 40% lower with subsidies in 2009-2013 (more fragmentation)
- Q/K is 20% lower with subsidies in 2009-2013

Impact on World Prices

Table: Impact of Subsidy on World Price

	Bulk	Tanker	Container
Subsidies, 2006-08	16.4	20.7	17.4
No subsidies, 2006-08	18.1	22.8	18.2
% difference	9.9%	10.1%	4.3%
Subsidies, 2009-13	8.8	6.4	9.0
No Subsidies, 2009-13	10.2	7.3	9.4
% difference	16.8%	14.8%	4.2%

Note: Prices in 1000 RMB/CGT

- Magnitude depends on supply and demand elasticity
  - Demand for containers more elastic hence effect smaller
- Effect larger in later period due to increased capacity and larger num. of firms

Impact on the World Industry

- Subsidies increased China's market share by 40%
  - China stole roughly equal market share from Japan and S. Korea
  - Profits by Japanese and South Korean shipyards reduce by 140 bn RMB
- Worldwide shippers benefit by 290 bill RMB
  - China accounts for less than 10% of world shippers

Subsidy Comparison

- How effective are these policies in generating profit and/or revenue?
- Production subsidy is static, while investment and entry subsidies have dynamic consequences
  - More investment and entry today imply more production and higher profit tomorrow
- Simulate long-run industry equilibrium from 2006-2050 (discounted profit post 2050 negligible)
  - Turning on and off subsidies as needed
  - Equilibrium prices are determined by supply and demand

Subsidy Comparison

Table: Comparison of Different Subsidies: Bill RMB

	All Subsidies	Only Production	Only Investment	Only Entry	No Subsidies
Lifetime Revenue 2006-2050	2361	2154	1873	1961	1810
Lifetime Profits 2006-2050	1085	1061	981	1023	950
Production Subsidy	262	225	0	0	0
Investment Subsidy	77	0	42	0	0
Entry Subsidy	431	0	0	231	0
Δ Revenue/Subsidy	72%	153%	153%	66%	
Δ Net Profit/Subsidy	18%	50%	74%	32%	

- Net Profit = (Profits-Investment Cost+Scrap Value-Entry Cost)
- Entry subsidies from 2006 to 2008 while production and investment subsidies from 2006 to 2050

Subsidy Comparison

- Production and investment subsidies can be justified by output considerations
- Entry subsidies attract high-cost firms and are wasteful
- Aggregate return to subsidies merely 18%
- Subsidies lead to higher aggregate fixed costs incurred, which augment inefficiency
  - Absent fixed costs, rate of return would increase from 18% to 25%
- Convexity: subsidies much more distortionary when combined

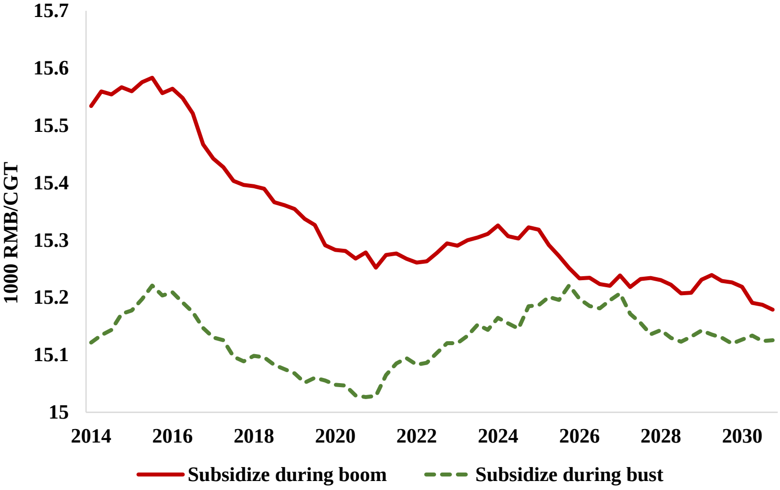
Business Cycle

Table: Pro-Cyclical vs. Counter-Cyclical Industrial Policy: Bill RMB

	Subsidize During Boom (2006-2008)	Subsidize During Recession (2009-2013)
Lifetime Revenue 2006-2050	1880	1872
Lifetime Profits 2006-2050	961	975
Production Subsidy	29	29
Investment Subsidy	13	14
Δ Revenue/Subsidies	189%	168%
Δ Net Profit/Subsidies	38%	70%

- Timing important: counter-cyclical policies out-perform pro-cyclical policies
  - expansion more costly during boom; firm composition different
- Actual policy mix is pro-cyclical: 560 bn of subsidies during boom, 60 bn during recession

Dynamic Composition



- Y-axis: average marginal cost index (a measure of firm efficiency)
- Subsidizing during recession selects more efficient firms over the long run
- Through more efficient entry and exit

Consolidation Policy

- The government released the "White List" in 2013
  - Publishes firms that meet 'industry standards'
  - Firms on the list receive priority in capital market access
- Policy justification
  - Facilitate consolidation
  - Create large firms to compete against international conglomerates
- Policy evaluation:
  - How effective is this policy?

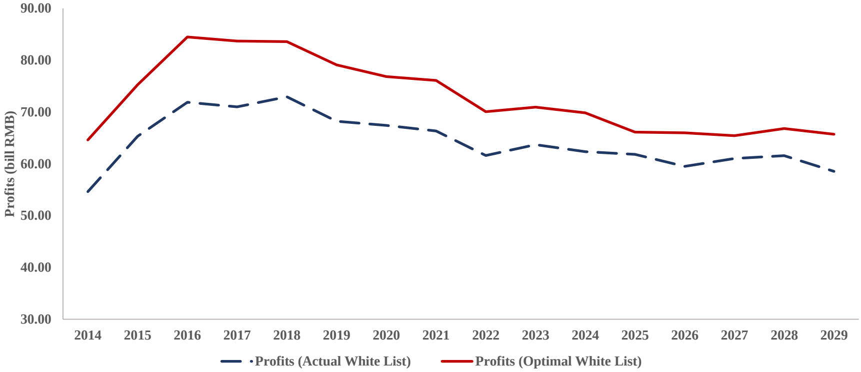
Consolidation Policy

Table: Effect of Consolidation Policy

	Subsidize all firms after 2013	Subsidize White List firms after 2013	No subsidies after 2013
Lifetime Revenue 2014-	922	882	793
Lifetime Net Profit 2014-	712	716	656
Production Subsidy	106	70	0
Investment Subsidy	40	13	0
Entry Subsidy	0	0	0
Δ Revenue/Subsidy	85%	105%	
Δ Net Profit/Subsidy	37%	71%	

- Targeting subsidies towards efficient firms leads to a substantially higher return

Consolidation Policy



- Profit 2014-2099: 465 (red, best) vs. 415 (blue, actual), a 12% difference
- Not selecting the best firms cuts gains from consolidation
- Selection biased toward SOEs

Alternative Designs of Industrial Policy

Towards Optimal Design

- We explore alternative, potentially more efficient ways to implement industrial policy
- 1. "Temporary" industrial policy
  - Subsidies only for production and investment
  - Government commits in advance to phasing out subsidies by end date T, known to all firms
- 2. "Temporary targeted" industrial policy
  - Same design as above, but target subsidies towards 50 most efficient firms
- Contrast both policy designs against a benchmark policy of "permanent" industrial policy
  - All firms eligible for subsidies
  - Subsidies continued indefinitely (no fixed end-date)

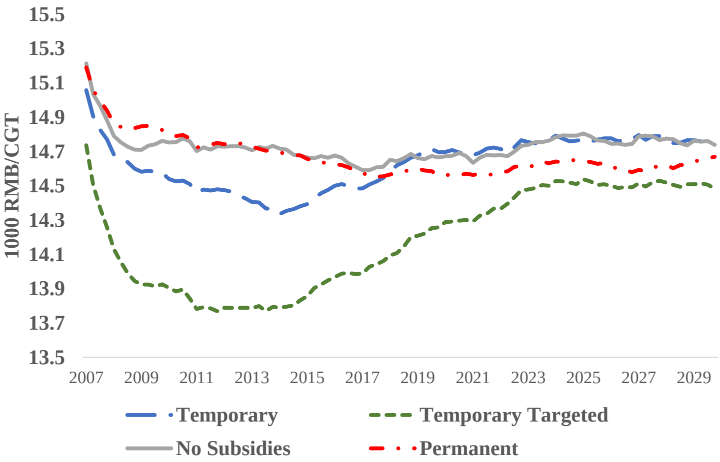
Alternative Policies

Table: Effect of Industrial Policy

	Perm.	Temp.	Temp. Targeted	No subsidies
Lifetime Revenue 2006-	1708	1655	1614	1366
Lifetime Net Profit 2006-	969	991	1035	853
Production Subsidy	193	201	191	0
Investment Subsidy	55	49	54	0
Entry Subsidy	0	0	0	0
Total Subsidy	248	250	245	
Δ Revenue/Subsidy	138%	116%	101%	
Δ Net Profit/Subsidy	47%	55%	75%	

- Temporary subsidies have a higher return
- Additional gains from targeting temporary subsidies towards efficient firms

Alternative Policies: Dynamic Composition



- Y-axis: average marginal cost index
- Temporary subsidies result in less fragmented industry and higher cost-efficiency
- *Targeting* temporary subsidies leads to even higher cost-efficiency

HHI | Number of firms | Per-firm capital

Varying Horizon

	Temp. 1 year	Temp. 3 years	Temp. 5 years	Temp. 8 years	Temp. 12 years	No subsidies
Lifetime Revenue 2006-	1481	1586	1614	1655	1666	1366
Lifetime Profits 2006-	972	1000	995	980	991	853
Production subsidies	205	206	201	201	201	0
Investment subsidies	38	51	48	49	50	0
Entry subsidies	0	0	0	0	0	0
Total Subsidies	243	257	248	250	251	
Δ Revenue/Subsidy	47%	86%	100%	116%	119%	
Δ Net Profit/Subsidy	49%	57%	57%	55%	51%	

- Vary horizon over which temporary industrial policy is implemented
- A horizon of 3-5 years appears to work best

Rationales for Industrial Policy

Rationales for IP: I

Traditional rationale of industrial policies:

- Strategic trade considerations

Strategic Trade Considerations

Table: Policy Returns with Perfect Competition

	All Subsidies	Production subsidies	Investment subsidies	Entry subsidies	Remove all subsidies
Lifetime Revenue 2006-	2253	2055	1786	1867	1716
Lifetime Net Profits 2006-	963	943	888	937	856
Production subsidies	267	227	0	0	0
Investment subsidies	78	0	42	0	0
Entry subsidies	412	0	0	217	0
Δ Revenue/Subsidy	71%	150%	166%	70%	
Δ Net Profit/Subsidy	14%	38%	74%	37%	

- Return on policy lower, but gap modest (14% instead of 18%)
- Strategic power considerations cannot justify industrial policy

Rationales for IP: I

Traditional rationale of industrial policies:

- Strategic trade considerations
  - Market power limited
- Marshallian externality
  - No evidence of industry wide learning-by-doing
- Spillover to other sectors and the labor market
  - Shipbuilding a small component (less than 1.5%) of steel demand
  - Limited spillover to downstream sectors (80% of ships are exported)
  - 8 jobs in shipbuilding and 26 in related sectors per $1 mill revenue
    - China's GDP per capita is $2,099 in 2006

Rationales for IP: II

Traditional rationale of industrial policies:

- Impact on trade
  - Subsidies reduced freight rates by 6% for bulk and 2% for container shipping
  - Trade elasticity: -1 for bulk (Brancaccio et al 2020) and -3.9 for container shipping (Jeon 2022)
  - IP raised China's total annual trade volume by $140 bn (subsidies averaged $11bn annually)
- Military (national security) considerations and the desire to be world no. 1
  - We provide cost estimates for achieving these objectives

Conclusion: I

- Massive (and wasteful) subsidies for the shipbuilding industry 2006-2013
  - China's world market share increased by 40%
  - At the cost of low concentration and capital utilization
- Effectiveness of the policies mixed:
  - Prod/inv subsidies could be justified by market share considerations
  - Entry subsidies are wasteful and increase fragmentation and idleness cost
  - Prod subsidy better at raising revenue; inv subsidy delivering a higher return

Conclusion: II

- Broad lessons: IP design can be first-order
  - Firm heterogeneity and targeting
  - The nature of business cycles and implementation timing
  - Firms' cost structure (extent of convexity)
  - Choices of policy instruments
- Our results speak to potential mechanisms underlying diverging IP outcomes
  - Some countries' support was conditioned on performance (East Asia), while others cannot weed out non-performing beneficiaries (Latin America)
  - Similar mechanism at work for China's shipbuilding:
    - Low return in earlier years when support was open-ended
    - High return in later years when support was channeled by White List

Thanks and Comments Welcome!

Appendix

Methodology for Counterfactual Analysis

- Key: new equilibrium prices and price transition process
- Assumption: prices follow AR1 in the new equilibrium

$$P_{m,t+1} = \Gamma(P_{mt}; \theta)$$

- Start from an initial guess θ^0, simulate a price path $\{P^0_{mt}\}$
- Solve firms' supply decisions (production/entry/investment) to obtain aggregate Q^s_{mt}
- Intersect with the demand curve Q^d_{mt} to obtain new equilibrium prices $\{P^1_{mt}\}$
- Update θ^1. Repeat till convergence

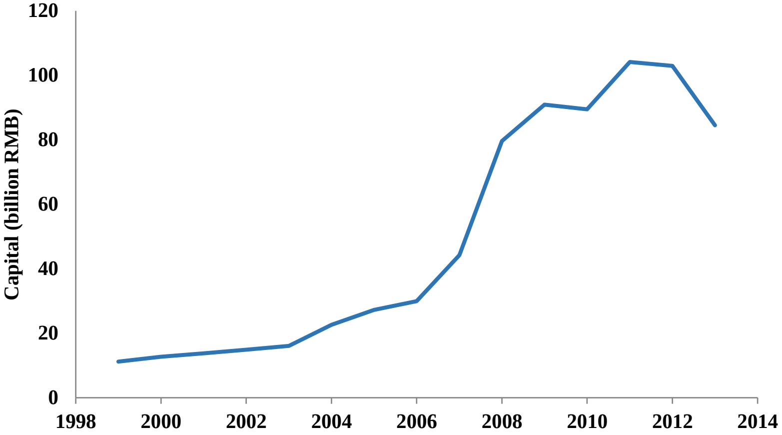
Central Government Initiatives for Consolidation

- Steel Policy 2005: promoted consolidation (but failed)
  - "Every region wanted its own steel mill and local governments were providing lavish benefits to build their steel industries" (CONSTID)
- Shipbuilding 2013: promote "top" firms (60% SOEs)
- *guo jin min tui* ("the state advances, the private sector retreats")
  - Stimulus package 2009: small/medium firms got 9% of 1.1$ trillion
  - (even though 70% of urban jobs) Go Back

Shandong in the 1990s

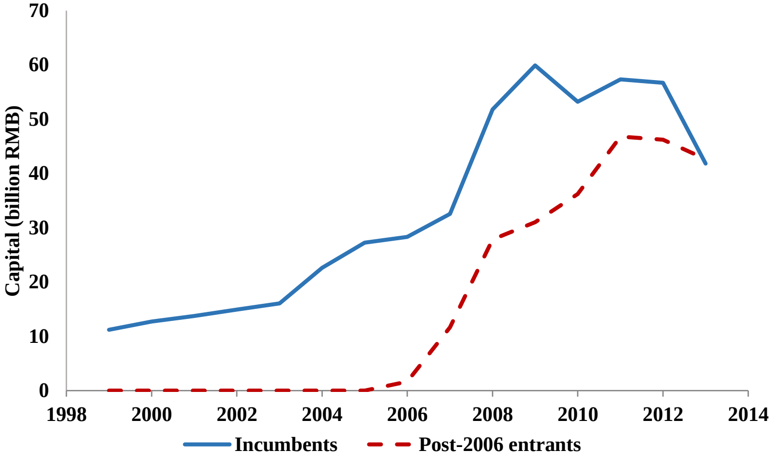
- In 1993 selects 136 groups for direct supervision
- In 1996 identifies 8 as "provincial champions"
  - tries to copy S. Korea (Samsung)
  - several measures: cheap supply of energy/inputs, unpayable loans..
  - some became inefficient SOEs, some national leaders Go Back

Capital Expansion



Go Back

Capital Expansion of Existing Firms



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Model: Dynamic Decisions

- J^e potential entrants. Each with a random entry cost κ_{jt}
- Value function

$$VE\left(s_{jt},\kappa_{jt}\right) = \max_{\chi^e_{jt}} \left\{ \begin{array}{c} \kappa_{jt}, \\ -C^I\left(K_{jt}\right) + \beta E\left[V\left(s_{jt+1}\right) | s_{jt}, \chi^e_{jt} = 1\right] \end{array} \right.$$

- Optimal entry policy

$$\chi^{e*}\left(s_{jt},\kappa_{jt}\right)$$

Go Back

Estimate Cost Function: Alternative Approach

- One approach is to back out the cost function using the estimated production function (OP/LP)

$$q_{jt} = f(k_{jt}, l_{jt}, m_{jt}, \omega_{jt})$$

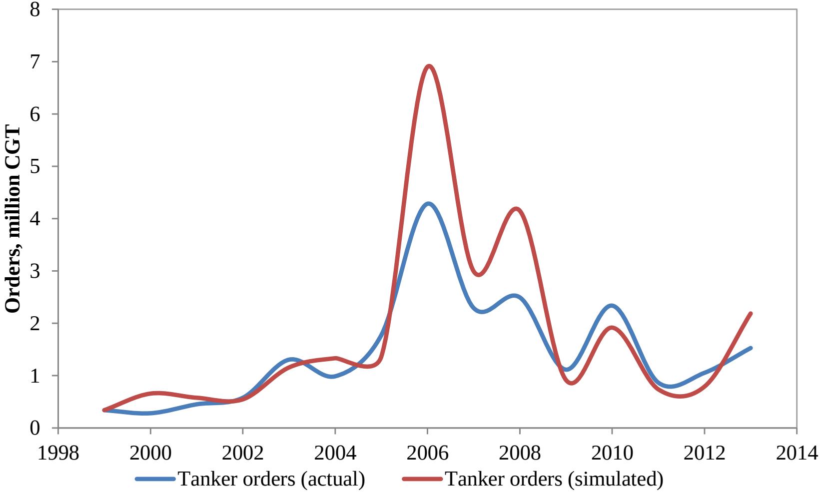
- Construct C_{jt} = labor costs + material costs + capital costs associated with quantity q_{jt}
- Challenge: data quality low
  - Reported costs unreliable
  - No inputs after 2007, etc. Go Back

Production Cost: Other Specifications

	Bulk carrier		Tanker		Containership	
	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
Baseline specification						
Capital (bill RMB)	-3.33	-2.98	-2.47	-1.53	-1.57	-1.28
Backlog	-2.45	-6.14	-5.45	-6.05	-3.58	-4.27
China 2006-2008	-3.60	-4.85				
China 2009+	-0.70	-1.02				
Add time trend						
Capital (bill RMB)	-3.40	-2.93	-2.51	-1.57	-1.60	-1.23
Backlog	-2.49	-6.06	-5.51	-5.90	-3.64	-3.99
China 2006-2008	-3.76	-4.48				
China 2009+	-0.87	-1.19				
Trend	0.03	0.50				
Existing yards						
Capital (bill RMB)	-3.98	-3.04	-3.26	-1.39	-0.48	-0.35
Backlog	-3.90	-5.71	-6.73	-5.77	-4.38	-3.94
China 2006-2008	-3.01	-3.03				
China 2009+	-0.92	-0.91				

Back

Goodness of Fit for Tanker Orders



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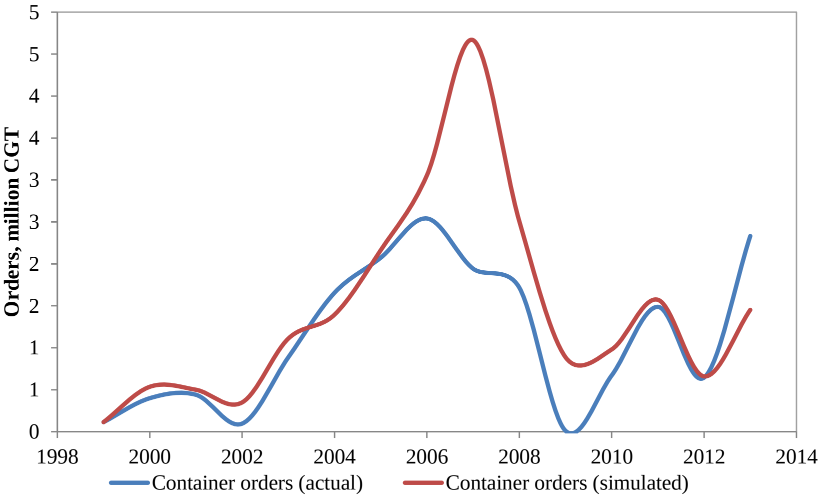
Goodness of Fit for Container Orders



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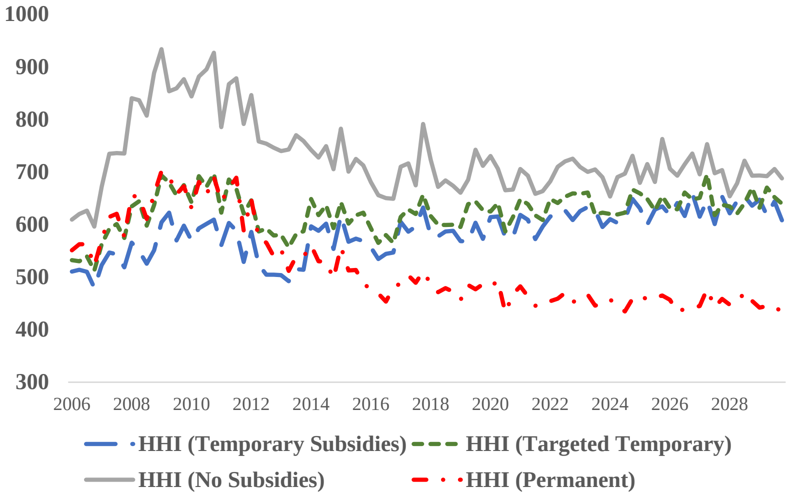
Alternative Policies: Industry Concentration



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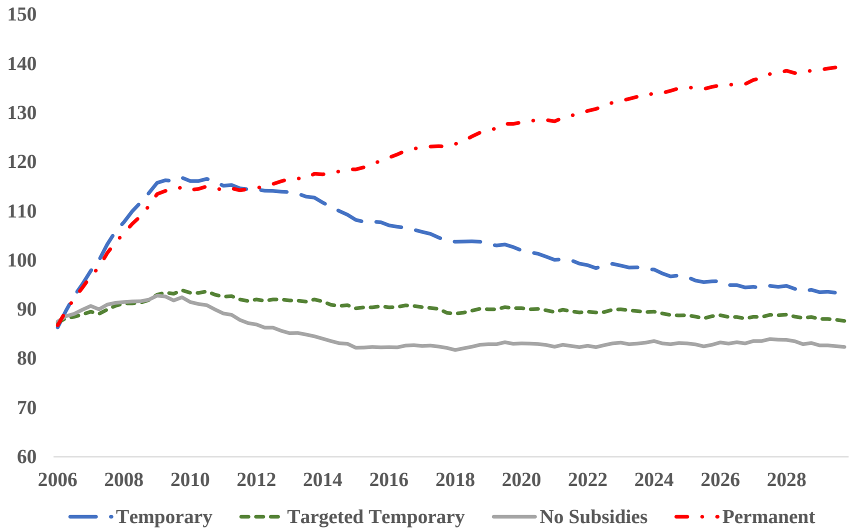
Alternative Policies: Number of firms



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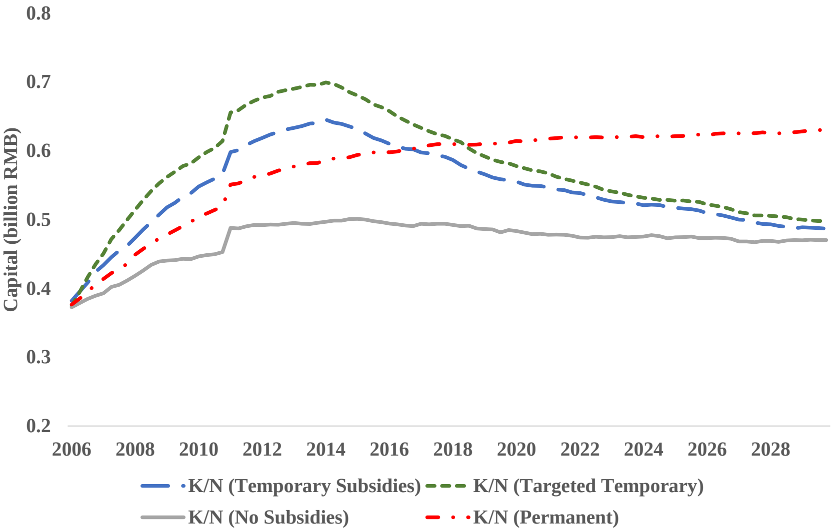
Alternative Policies: per-firm capital



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