

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

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Abstract

Industrial policies are widely used across the world. In practice, designing and implementing these policies is a complicated task. In this paper, we assess the long-term performance of different industrial policy instruments, which include production subsidies, investment subsidies, entry subsidies, and consolidation policies. To do so, we examine a recent industrial policy in China aiming to propel the country's shipbuilding industry to the largest globally. Using firm-level data from 1998 to 2014 and a dynamic model of firm entry, exit, investment, and production, we find that (i) the policy boosted China's domestic investment, entry, and international market share dramatically, but delivered low returns and led to fragmentation, idle capacity, as well as depressed world ship prices; (ii) the effectiveness of different policy instruments is mixed: production and investment subsidies can be justified by market share considerations, while entry subsidies are wasteful; (iii) counter-cyclical policies, firm-targeting, and shortening the intervention horizon can substantially reduce distortions. Our results highlight the critical role of firm heterogeneity, business cycles, and firms' cost structure in policy design. Finally, when exploring potential rationales, we find support for non-classical considerations, such as reducing freight rates to boost Chinese trade.

Keywords: Industrial policy, China, Investment, Dynamics, Shipbuilding

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1 Introduction

Industrial policy has been widely used in both developed and developing countries. Examples include the U.S. and Europe after World War II, Japan in the 1950s and 1960s (Johnson, 1982; Ito, 1992), South Korea and Taiwan in the 1960s and 1970s (Amsden, 1989; Lane, 2022), China, India, Brazil, and other developing countries more recently (Stiglitz and Lin, 2013; Peres, 2013). It is also back in the spotlight in developed countries, such as Europe and the US.¹ Designing and implementing industrial policies is a complicated task. Governments seeking to promote the growth of selected sectors have a wide range of policy tools at their disposal, including subsidies on output, provision of loans at below-market interest rates, preferential tax policies, tariff and non-tariff barriers, and so on. They must also choose the timing of policy interventions and whether to target selected firms within an industry. As Rodrik (2010) puts it, “The real question about industrial policy is not whether it should be practiced, but how.” This paper tackles precisely this question.

We focus on China’s shipbuilding industry which provides a clear illustration of the challenges associated with designing effective industrial policies. At the turn of the century, China’s nascent shipbuilding industry accounted for less than 10% of the world production. During the 11th (2006-2010) and 12th (2011-2015) National Five-Year Plans, shipbuilding was dubbed a pillar industry in need of special oversight and consequently received numerous policy interventions. Within a few years, China overtook Japan and South Korea to become the world’s leading ship producer in terms of output. However, this impressive output growth was achieved via a massive wave of new firms, which exacerbated industry fragmentation and low capacity utilization.² Plummeting ship prices during the aftermath of the financial crisis threatened the survival of many firms in the industry and prompted the government to place a moratorium on the entry of new firms. In the meantime, policy support was shifted towards selected firms on a “White List” in an effort to promote industry consolidation.³

The example of shipbuilding, which echoes patterns observed in other industries (steel, solar panels, auto, etc.), highlights the complexity of designing industrial policies and the difficulties associated with empirically evaluating past experiences. Policies that are implemented are often opaque; in addition, outcomes are affected by a large number of considerations, such as industry dynamics, business cycles, and firm heterogeneity. As a result, relative to the large theoretical literature on industrial policy and its popularity in practice, the empirical analysis is much more limited (see Lane, 2020 and Juhász et al., 2023 for excellent reviews).

¹See *The Economist* 2019: <https://www.economist.com/europe/2019/02/21/how-china-has-pushed-germany-to-rethink-industrial-policy>.

²This pattern is not unique to the shipbuilding industry. In many other industries that received government support in China in the 1990s and 2000s, such as steel, auto, and solar panels, sector growth was also characterized by the proliferation of small firms and an overall fragmented industry structure (Figure A1). This is in contrast to the experience of other countries. For example, South Korea’s industrial policy of promoting heavy industries in the late 1970s ended up contributing to the dominance of large business conglomerates or the “chaebol” (Fukagawa, 1997).

³The “White List” consists of firms that “meet the industry standard” and thus receive priority in government support. See Section 2 for more details. Throughout this paper, we use “firms” and “shipyards” interchangeably.

This paper addresses two sets of questions. First, how did China's industrial policy affect the evolution of both the domestic and global industry? Second, what is the relative performance of different policy instruments, which include production subsidies (e.g., subsidized material inputs, export credits, buyer financing), investment subsidies (e.g., low-interest long-term loans, expedited capital depreciation), entry subsidies (e.g., below-market-rate land prices), and consolidation policies (White Lists)?

We first develop a structural model of the industry that incorporates dynamics and firm heterogeneity, both of which are essential for determining the long-term implications of industrial policy. In each period, firms engage in Cournot competition: they choose output subject to convex production costs and charge a markup. Then they decide whether or not to exit and how much to invest conditional on staying. Investment increases firm capital, which in turn reduces future production costs. Potential entrants make entry decisions based on their expected lifetime profitability and entry costs. China's industrial policy affects all of these decisions by lowering the relevant costs.

We then estimate the model using data on firm-level output, capital, and characteristics, as well as ship market prices from 1998 to 2014. The main primitives of interest are firm production costs, investment costs, entry costs, exit scrap values, the demand for ships, as well as the magnitude of subsidies. A critical challenge in our analysis is the lack of information on the nature of government subsidies. Partly because international trade agreements prohibit direct and in-kind subsidies, "systematic data are non-existent" (WTO, 2006) and thus the presence and magnitude of such subsidies are often unknown. This is a real hurdle to both domestic and international regulators who adjudicate subsidy disputes. To overcome this challenge, we follow the existing literature (see the literature review below) and recover the magnitude of subsidies by estimating the cost structure of Chinese firms before and after the policies were implemented, and in comparison to other countries when possible. Although this approach has its own caveats, it is the only feasible strategy next to observing the subsidies directly.

Our empirical strategy departs from the literature on firm dynamic decisions in two ways. First, we estimate the fixed costs of production from accounting data to accommodate sample periods when idling capacity and zero production plagued the industry. Second, we allow for continuous investment with unobserved cost shocks and adjustment costs in light of heterogeneous investment across firms with similar attributes. Once the key parameters are uncovered, we evaluate the long-term implications of China's industrial policy in counterfactual analysis, simulating the global shipbuilding industry over time and turning on and off different policy instruments as needed. Methodologically, our framework is quite general and can be adapted to the evaluation of other sector-specific industrial policies.

Our analysis delivers four sets of main findings. First, like many other policies unleashed by China's central government in the past decades, the scale of the policy is massive compared to the size of the shipbuilding industry. The discounted sum of subsidies (measured in constant RMB in the year 2000) is estimated at RMB 624 billion (\$91 billion), with entry subsidies accounting for RMB 431 bn, followed by production subsidies at RMB 156 bn and investment subsidies at RMB 37 bn. Our estimates suggest that the policy support from 2006 to 2013 boosted China's domestic investment and entry by 140% and 120%, respectively, and increased its world market share by over 40%. Importantly, 70% of this

expansion occurred via business stealing from rival countries (Japan and South Korea). These estimates corroborate raw data patterns. For example, aggregate investment by Chinese firms remained elevated post the financial crisis despite plummeting ship prices during the global recession.

On the other hand, the policy generated modest gains in domestic producers' profit and worldwide consumer surplus. In the long run, the gross return rate of the adopted policy mix, as measured by the lifetime profit gains of domestic firms divided by total subsidies, is only 18%. The policy attracted a large number of inefficient producers and exacerbated the extent of excess capacity. Fixed costs of production further contributed to the low returns due to the volatile nature of the industry and firm idleness.

Second, the effectiveness of different policy instruments differs greatly. Production and investment subsidies can be justified if the goal is revenue maximization (the rate of return as measured by the ratio of increased industry revenue to subsidies is 153%), but entry subsidies are wasteful even by the revenue metric and lead to increased industry fragmentation and idleness. This is because entry subsidies attract small and inefficient firms; in contrast, production and investment subsidies favor large and efficient firms that benefit from economies of scale. Finally, distortions are convex so that the rate of return deteriorates when policies are used in conjunction, as is done in practice.

Third, our analysis suggests that the efficacy of industrial policy is significantly affected by the presence of boom and bust cycles, as well as by heterogeneity in firm efficiency, both of which are notable features of the shipbuilding industry. A counter-cyclical policy would outperform the pro-cyclical policy that was adopted by a large margin. Indeed, their effectiveness at raising long-term industry profit differs by nearly twofold, which is primarily driven by a composition effect (more low-cost firms operate in a bust compared to a boom) and the much more costly expansion during booms (due to convex production and investment costs). In addition, shortening the horizon over which the policy is implemented could further boost the returns, as temporary interventions mitigate the entry of inefficient firms and reinforce the increasing returns to scale in ship production, all else equal.

Fourth, we examine the consolidation policy adopted in the aftermath of the financial crisis, whereby the government implemented a moratorium on entry and issued a "White List" of firms that are prioritized for government support. This strategy was adopted in several industries to curb excess capacity and create national champions that can compete globally.⁴ Consistent with the evidence discussed above, we find that targeting low-cost firms significantly reduces distortions. That said, the government's White List was suboptimal and favored state-owned enterprises (SOEs) at the expense of the most efficient firms.

Our results highlight potential mechanisms underlying industrial policies' diverging outcomes across countries. For instance, in East Asian countries where industrial policy was considered successful, the policy support was often conditioned on performance. In contrast, in Latin America where industrial policies were less effective, there were no mechanisms to weed out non-performing beneficiaries (Rodrik, 2009). Our analysis illustrates that similar mechanisms are at work in China's modern-day industrial policy in the shipbuilding industry. The policy's return was low in earlier years when output expansion was primarily fueled by the entry of inefficient firms, but increased considerably over time as the gov-

⁴See <https://www.wsj.com/articles/SB10001424127887324624404578257351843112188>.

ernment used ‘performance-based’ criteria (the White List) to channel subsidies. Such targeted policy design is substantially more successful than open-ended policies that benefit all firms.

Finally, we examine possible rationales for the policy we study. Strategic trade considerations are largely irrelevant because the shipbuilding industry is fragmented globally and market power is limited. There is no evidence of industry-wide learning-by-doing (Marshallian externalities), another common rationale for industrial policy. In terms of spillovers to the rest of the economy, we find limited evidence that the shipbuilding industry generates significant spillovers to other domestic sectors (e.g., steel production or the labor market).

On the other hand, the substantial increase in the global fleet ensuing from China’s increase in ship production did lower freight costs and increased China’s imports and exports. Our (back of the envelope) calculations indicate that government subsidies, which averaged \$11.3bn annually between 2006 and 2013, lowered freight rates by 6% and boosted China’s trade volume by 5%, or \$144bn annually.⁵ That said, evaluating the welfare gains of the associated increase in trade volume requires a general equilibrium trade model and falls beyond the scope of this paper. There is also some evidence that military ship production might have benefited from China’s industrial policy: military ship production is concentrated at state-owned yards with commercial ship production and increased severalfold during the same period. However, this is suggestive due to limited data coverage. Regardless of the motivation, our analysis estimates the policy’s costs and assesses the relative efficacy of different policy instruments.

Related Literature There is a large theoretical literature on industrial policy (Hirschman, 1958; Baldwin, 1969; Krueger, 1990; Krugman, 1991; Harrison and Rodriguez-Clare, 2010; Stiglitz et al., 2013; Itskhoki and Moll, 2019). The earlier empirical literature on industrial policy mostly focuses on describing what happens to the benefiting industries (or countries) with regards to output, revenue, and growth rates (Baldwin and Krugman, 1988; Head, 1994; Luzio and Greenstein, 1995; Irwin, 2000; Hansen et al., 2003), while recent studies recognize the importance of measuring the impact on productivity and cross-sector spillovers (Aghion et al., 2015; Lane, 2022; Liu, 2019; Manelici and Pantea, 2021; Choi and Levchenko, 2021; Juhász et al., 2022). Related literature analyzes trade policies, in particular export subsidies (Das et al., 2007), R&D subsidies (Hall and Van Reenen, 2000; Bloom et al., 2002; Wilson, 2009), place-based policies targeting disadvantaged geographical areas (Kline and Moretti, 2014; Neumark and Simpson, 2015; Criscuolo et al., 2019), and environmental subsidies (Yi et al. 2015; Aldy et al. 2018).

Much of the existing literature focuses on whether an industrial policy should be implemented and which sectors should be targeted. Our analysis is complementary to the literature. We take a targeted sector as given and examine the design of industrial policy, a question that has received much less attention in prior work. To the best of our knowledge, our paper provides the first structural analysis of the design and performance of a large-scale industrial policy using firm-level data. The key features of our analysis are rich firm heterogeneity and market power, real business cycles and firm dynamics, and a variety of policy instruments. How industrial policy is implemented can radically affect the dynamic evolution of

⁵The conversion rate for this period was 6.88 RMB for 1 U.S. dollar.

an industry. At the same time, different policy instruments entail very different returns.

Our paper also contributes to the growing literature studying how China’s industrial development has been shaped by a variety of policy interventions, including consolidation policies (Rubens, 2021), R&D tax incentives (Chen et al., 2021), and value-added (VAT) tax reforms (Liu and Mao, 2019; Chen et al., 2019; Bai and Liu, 2019). In addition, our study builds on an emerging literature on the shipbuilding industry (Thompson, 2001, 2007; Hanlon, 2020). Kalouptsidi (2018) is closely related to our paper and detects evidence of production subsidies for a subset of bulk carriers (Handysize). In contrast, we examine the design, implementation, and efficacy of China’s overall industrial policy and its impact on the global shipbuilding industry.

Methodologically, we build on the literature on dynamic estimation, including Bajari et al. (2007); Akerberg et al. (2007); Pakes et al. (2007); Xu (2008); Aw et al. (2011); Ryan (2012); Collard-Wexler (2013); Sweeting (2013); Barwick and Pathak (2015); Fowlie et al. (2016), as well as the macro literature on firm investment (Abel and Eberly, 1994; Cooper and Haltiwanger, 2006). Complementing the macro literature that focuses on inaction (zero investment) and adjustment costs, our approach can rationalize different investment chosen by observably similar firms, while accommodating inaction and adjustment costs. Our analysis of firm investment builds on Akerberg et al. (2007) and provides one of the first empirical applications of this model with continuous investment. This approach can be used in a variety of settings where heterogeneity in investment is an important consideration. In addition, our framework is quite general and can be easily adapted to the evaluation of other sector-specific industrial policies. Finally, our approach to estimating the subsidies follows a long tradition in the literature (Bruce, 1990; Young, 2000; Anderson and Van Wincoop, 2004; Poncet, 2005; Kalouptsidi, 2018; Barwick et al., 2020; Bai and Liu, 2019).

The rest of the paper is organized as follows. Section 2 provides an overview of China’s shipbuilding industry and discusses the relevant industrial policy and our datasets. Section 3 presents the model. Sections 4 and 5 describe the estimation strategy and empirical results. Section 6 quantifies the policy impact on industry evolution and examines the performance of different policy instruments. Section 7 evaluates traditional rationales for industrial policy. Section 8 concludes.

2 Industry Background and Data

2.1 Industry Background

Shipbuilding is a classic target of industrial policy, often seen as a strategic industry for both commercial and military purposes. During the late 1800s and early 1900s, Europe was the dominant ship producer, especially the UK. After World War II, Japan subsidized shipbuilding along with several other industries to rebuild its industrial base and became the world’s leader in ship production. South Korea went through the same phase in the 1970s and 1980s. In the 2000s, China supported the shipbuilding industry via a broad set of policy instruments.

The scope of national policies issued in China in the 2000s, especially after 2005, to support its shipbuilding industry is unprecedented. In 2002, former Premier Zhu inspected the China State Shipbuilding Corporation (CSSC), one of the two largest shipbuilding conglomerates in China, and pointed out that “China hopes to become the world’s largest shipbuilding country (in terms of output) [...] by 2015.” Soon after, the central government issued the 2003 *National Marine Economic Development Plan* and proposed constructing three shipbuilding bases centered at the Bohai Sea area (Liaoning, Shandong, and Hebei), the East Sea area (Shanghai, Jiangsu, and Zhejiang), and the South Sea area (Guangdong).

The most important initiative was the 11th National Five-Year Economic Plan (2006-2010) which dubbed shipbuilding as a strategic industry. Since then, the shipbuilding industry, together with the marine equipment industry and the ship-repair industry, has received numerous supportive policies. Zhejiang was the first province that identified shipbuilding as a provincial pillar industry. Jiangsu is the close second and set up dedicated banks to provide shipyards with favorable financing terms. In the 11th (2006-2010) and 12th (2011-2015) Five-Year plans, shipbuilding was identified as a pillar or strategic industry by twelve and sixteen provinces, respectively. Besides these Five-Year Plans, the central government issued a series of policy documents with specific production and capacity goals. For example, as part of the 2006 *Medium and Long Term Development Plan of Shipbuilding Industry*, the government set an annual production goal of 15 million deadweight tons (DWT) by 2010 and 22 million DWT by 2015. Both goals were met several years in advance. Table A1 and Appendix A.1 document major national policies issued during our sample period.

We group policies that supported the Chinese shipbuilding industry into three categories based on policy documents: production, investment, and entry subsidies. Production subsidies lower the cost of producing ships. For instance, the government-buttressed domestic steel industry provides cheap steel, which is an important input for shipbuilding. Besides subsidized input materials, export credits (Collins and Grubb, 2008) and buyer financing in the form of collateral loans provided by government-directed banks constitute other important components of production subsidies.⁶ Buyer financing is important because shipyards have traditionally offered loans and financial services to facilitate purchasing payments and attract buyers. Investment subsidies take the form of low-interest long-term loans and preferential tax policies that allow for accelerated capital depreciation.⁷ Finally, shortened processing time and simplified licensing procedure, as well as heavily subsidized land prices along the coastal regions greatly lower the entry costs for potential shipyards.

In response to the 2008 economic crisis that led to a sharp decline in global ship prices and in an effort to curb excess capacity and industry fragmentation, the government unveiled the 2009 *Plan on Adjusting and Revitalizing the Shipbuilding Industry* that resulted in an immediate moratorium on entry with increased investment subsidies to existing firms. This marked an important shift in China’s policy in this sector, where government support moved toward facilitating consolidation and creating

⁶Until 2016, the Chinese government subsidized exporters using reduced corporate income taxes and refund of the value-added-tax, etc. Shipyards benefit from export subsidies since their products are mostly traded internationally.

⁷China implemented a value-added tax reform in 2009 that might have stimulated investment (Chen et al., 2019). This policy has limited impacts on shipyards, which are already exempt from value-added tax via exports subsidies.

large, successful firms that can compete against international conglomerates. The most crucial policy for achieving consolidation was the *Shipbuilding Industry Standard and Conditions* (2013), which instructed the government to periodically announce a list of firms that “meet the industry standard” and thus receive priority in subsidies and bank financing.⁸ The so-called “White List” included sixty firms in 2014 upon announcement.

In this paper, we focus on the production of three ship types: dry bulk carriers, tankers, and containerships, which account for more than 90% of world orders in tons in our sample period. Dry bulk carriers transport homogeneous and unpacked goods, such as iron ore, grain, coal, and steel for individual shippers on non-scheduled routes. Tankers carry chemicals, crude oil, and other oil products. Containerships carry containerized cargo from different shippers in regular port-to-port itineraries. As these types of ships carry entirely different commodities, they are not substitutable. We thus treat them as operating in separate markets.

Shipbuilding worldwide is concentrated in China, Japan, and South Korea, which account for over 90% of the world production. We limit our empirical analysis to these three countries.

2.2 Data

Our empirical analysis draws on a number of datasets. The first dataset comes from Clarksons and contains quarterly information on all shipyards worldwide that produce ships for ocean transport between the first quarter of 1998 and the first quarter of 2014 (Clarksons Research, 2015). We observe each yard’s orders, deliveries, and backlog (which are undelivered orders that are under construction) measured in Compensated Gross Tons (CGT), for all major ship types, including bulk carriers, tankers, and containerships. CGT, which is a widely used measure of size in the industry, takes into consideration production complexities of different ships and is comparable across types.

The second data source is the annual database compiled by China’s National Bureau of Statistics (NBS) on manufacturing firms (NBS, 2015). For each shipyard and year, we observe its location (province and city), balance-sheet information (including total fixed assets), and ownership status (state-owned enterprises (SOEs), privately owned, or joint ventures). We link firms over time and construct their real capital stock and investment from total fixed assets following Brandt et al. (2012), which is standard practice in the literature.⁹ We differentiate SOEs that are part of China State Shipbuilding Corporation (CSSC) and China Shipbuilding Industry Corporation (CSIC), the two largest shipbuilding conglomerates in China, from other SOEs.

In addition to these firm-level variables, we collect a number of aggregate variables, including quarterly global prices per CGT for each ship type (Clarksons Research, 2017). The steel ship plate price serves as a cost shifter, as steel is a major input in shipbuilding. We merge all datasets to obtain a quarterly panel of Chinese, South Korean, and Japanese shipyards ranging from 1998 to 2013. All monetary

⁸In practice, favorable financing terms and capital market access are often limited to firms on the White List post 2014.

⁹One limitation is that data for 2010 are missing. This prevents us from constructing firm-level investment in either 2009 or 2010 since investment is imputed from year-to-year changes in capital stock.

variables (such as investment and capital) are in real terms and measured in 2000 RMB. Appendix A.2 provides more details on variable construction and descriptive patterns.

2.3 Descriptive Evidence and Summary Statistics

Similar to many other manufacturing industries in China, the shipbuilding industry experienced exponential growth since the mid 2000s. China became the largest shipbuilding country in terms of CGT in 2009, overtaking South Korea and Japan. Panel (a) of Figure 1 plots China's rapid ascent into global influence from 1998 to 2013. At the same time, a massive entry wave of new shipyards occurred along China's coastal areas. Panel (b) plots the total number of new shipyards by year. The number of entrants is modest for Japan (1.4 per year) and South Korea (1.2 per year). In contrast, the number of new shipyards in China registered a historic record and exceeded 30 per year during the boom years when the entry subsidies were in place. Entry dropped to 15 in 2009 and became minimal within a couple of years of the implementation of the 2009 entry moratorium, as part of the *Plan on Adjusting and Revitalizing the Shipbuilding Industry*.¹⁰

The rise in entry was accompanied by a large and unprecedented increase in capital expansion (Panel (c) of Figure 1). The year of 2006 alone witnessed a steep four-fold increase in investment. The capital expansion was universal across both entrants and incumbents and among firms with different ownership statuses. For example, entrants accounted for 43% of the aggregate investment from 2006 to 2011, with the remaining 57% implemented by incumbents. Private firms, joint ventures, and SOEs accounted for 25%, 36%, and 38% of total investment, respectively. In addition, the capital expansion was spread out across provinces, though Jiangsu accounted for a disproportionate share of 40% of the aggregate investment between 2006 and 2011 (Figure A2).

The rapid rise in China's entry, production, and investment aligned remarkably well with the policy timelines. In contrast, the economic fundamentals (or market forces) do not appear to fully rationalize these data patterns. As Panel (d) of Figure 1 shows, ship prices began rising around 2003, peaked in 2008, collapsed in the aftermath of the financial crisis, and remained stagnant from 2009 to 2013. China's production and investment, on the other hand, continued to expand well after the financial crisis, in contrast to other countries.

Table 1 contains summary statistics on key variables of interest. There are a large number of firms, with 266 Chinese shipyards, 108 Japanese shipyards, and 46 Korean shipyards. Industry concentration is low, with a world HHI that varies from 230 to 720 during the sample period.

An important feature of ship production is that shipyards take new orders infrequently, about 23% of the quarters for bulkers and less frequently for tankers and containerships. From 2009 onwards, during a prolonged period of low ship prices, the frequency with which yards took new orders was significantly lower. This lumpiness in ship orders that rendered Chinese shipyards increasingly vulnerable to long

¹⁰No new applications were processed post 2009, but projects already approved were allowed to be completed. In addition, firms registered prior to 2009 but engaged in repairs and marine engineering could 'enter' and produce ships post 2009. Both account for the entry (though at a far reduced rate) past 2009.

periods of inaction during the recession, is a key feature of the industry that informs our modeling choices in Section 3.

Finally, about 52% of firms in our sample produce one ship type, a pattern that holds across countries. The fraction of shipyards that produce all three ship types is higher in South Korea (28%) and Japan (16%) and lower in China (14%). If a shipyard never takes orders for a certain ship type throughout our sample, it is assumed not to produce this ship type.

3 Model

In this section, we introduce a dynamic model of firm entry, exit, and capital investment. In each period, incumbent firms engage in Cournot competition by choosing statically how much to produce. Then they choose whether or not to exit, and conditional on staying, how much to invest. A pool of potential entrants make one-shot entry decisions based on their expected discounted stream of profits and entry costs. At the end of the period, entry, exit, and investment decisions are implemented and the state evolves to the next period.

Time is discrete and a period is a quarter. In period t , there are $j = 1, \dots, J_t$ firms. Ship type (dry bulk carriers, tankers, and containerships) is denoted by m . Ships within a type are homogeneous.

Ship Demand The aggregate inverse demand for ship type m at time t is given by:

$$P_{mt} = P_m(Q_{mt}, d_{mt}) \quad (1)$$

for $m = 1, \dots, M$, where P_{mt} is the price of ship type m in period t , Q_{mt} is the total CGT demanded, and d_{mt} are demand shifters, such as freight rates and aggregate indicators of economic activity.

Ship Production Firm j produces q_{jmt} tons at the following cost:

$$C(q_{jmt}, s_{jmt}, \omega_{jmt}) = c_0 + c_m(q_{jmt}, s_{jmt}, \omega_{jmt})$$

where c_0 is a fixed cost that is incurred even when shipyards have zero production, such as wages and benefits for managers, capital maintenance, land and rental costs, etc. Fixed costs are often abstracted away in empirical studies. In our context, where aggregate demand for new ships plummeted post the financial crisis and many shipyards reported prolonged periods with zero production, fixed costs constitute a substantial fraction of overall costs and thus should not be omitted.

The second term, $c_m(q_{jmt}, s_{jmt}, \omega_{jmt})$, is the variable production cost. We use s_{jmt} to denote firm characteristics (e.g. capital, backlog, age, location, ownership status), aggregate cost shifters that affect all shipyards (e.g. steel prices), and policy dummies that capture the effect of industrial policy on production costs. In addition, production costs depend on shock ω_{jmt} : the larger ω_{jmt} is, the less productive the firm is.

Firms engage in Cournot competition. They choose how many tons of ship type m to produce in each period, q_{jmt} , taking as given the production decisions of rival firms.

If the optimal production tonnage for type m , q_{jmt}^* , is positive, it satisfies the following first order condition:

$$P_{mt} + q_{jmt}^* \frac{\partial P(Q_{mt}, d_{mt})}{\partial q_{jmt}} = MC_m(q_{jmt}^*, s_{jmt}, \omega_{jmt}) \quad (2)$$

where $MC_m(q_{jmt}, s_{jmt}, \omega_{jmt})$ is the marginal cost of producing type m . Firms charge a markup equal to $q_{jmt}^* \frac{\partial P(Q_{mt}, d_{mt})}{\partial q_{jmt}}$ (in absolute value), thus distorting the market output levels.

Firm Profit Let $s_{jt} = \{s_{j1t}, \dots, s_{jMt}\}$ denote firm j 's state variable at time t , which is the union of its state variables across ship types, the states of its rivals, as well as aggregate states. Industrial policies affect the costs of production, investment, and entry and are part of the payoff relevant state variables, s_{jt} . Firm j 's expected profit from all types, before the cost shocks are realized, is:

$$\pi(s_{jt}) = \mathbb{E} \sum_{m=1}^M \pi_m(s_{jt}, \omega_{jmt})$$

where $\pi_m(s_{jt}, \omega_{jmt})$ is firm j 's profit from producing ship type m , and $\mathbb{E}$ integrates out uncertainties in firms' production cost shocks.¹¹

Finally, in each period, the prevailing ship price, P_{mt} , equates aggregate demand and supply, where the aggregate supply is the sum of q_{jmt}^* defined in (2).

Investment and Exit Once firms make their optimal production choice, they observe a private scrap (sell-off) value, ϕ_{jt} , that is i.i.d. with distribution F_ϕ and decide whether to remain in operation or exit. If a firm chooses to exit, it receives the scrap value. If it remains active, it observes a firm-specific random investment cost shock, v_{jt} , that is i.i.d. with distribution F_v , and chooses investment i_{jt} at cost $C^i(i_{jt}, s_{jt}, v_{jt})$. The amount invested, i_{jt} , is added to the firm's capital stock next period, which in turn affects its future production costs.

Let $V(s_{jt}, \phi_{jt})$ denote the ex-post value function after firm j observes its scrap value and $V(s_{jt})$ denote the ex-ante value function before the realization of the scrap value: $V(s_{jt}) \equiv \mathbb{E}_{\phi} V(s_{jt}, \phi_{jt})$. The ex-post value function for incumbent firm j is:

$$V(s_{jt}, \phi_{jt}) = \pi(s_{jt}) + \max \left\{ \phi_{jt}, \mathbb{E}_{v_{jt}} \left(\max_i \left(-C^i(i, s_{jt}, v_{jt}) + \beta \mathbb{E} [V(s_{jt+1}) | s_{jt}, i] \right) \right) \right\} \quad (3)$$

$$= \pi(s_{jt}) + \max \{ \phi_{jt}, CV(s_{jt}) \}$$

$$CV(s_{jt}) \equiv \mathbb{E}_{v_{jt}} \left(-C^i(i^*, s_{jt}, v_{jt}) + \beta \mathbb{E} [V(s_{jt+1}) | s_{jt}, i^*] \right) \quad (4)$$

where $CV(s_{jt})$ denotes the continuation value, which includes the expected cost of optimal investment

¹¹We take firms' product types as given and do not explicitly model their choice of which ship types to produce.

and the discounted future stream of profits. In addition, $\mathbb{E}_{v_{jt}}$ is the expectation with respect to the random investment cost shock v_{jt} and i^* denotes the optimal investment policy $i^* = i^*(s_{jt}, v_{jt})$.

The optimal exit policy is of the threshold form: firm j exits the market if the drawn scrap value ϕ_{jt} is higher than its continuation value $CV(s_{jt})$. Since the scrap value is random, the firm exits with probability $p^x(s_{jt})$:

$$p^x(s_{jt}) \equiv \Pr(\phi_{jt} > CV(s_{jt})) = 1 - F_\phi(CV(s_{jt})) \quad (5)$$

where F_ϕ is the distribution of ϕ_{jt} .

Conditional on staying, firm j observes its investment shock, v_{jt} . Its optimal investment $i^* = i^*(s_{jt}, v_{jt})$, which is non-negative, satisfies the first-order condition:

$$\beta \frac{\partial \mathbb{E}[V(s_{jt+1})|s_{jt}, i^*]}{\partial i} \leq \frac{\partial C^i(i^*, s_{jt}, v_{jt})}{\partial i} \quad (6)$$

with equality if and only if the optimal investment is strictly positive, $i^*(s_{jt}, v_{jt}) > 0$. When the investment costs are prohibitively high or the expected benefit too low, firms opt for no investment. Capital depreciates at rate δ that is common to all firms.

We assume that the cost of investment, $C^i(i_{jt}, s_{jt}, v_{jt})$, has the following form:

$$C^i(i_{jt}, s_{jt}, v_{jt}) = c_1(s_{jt})i_{jt} + c_2i_{jt}^2 + c_3v_{jt}i_{jt} \quad (7)$$

This quadratic specification borrows from the macro literature on convex investment costs (e.g. [Cooper and Haltiwanger 2006](#)) with some important differences. For example, investment costs depend on the unobserved marginal cost shock v_{jt} . Much of the existing literature has focused on the lumpy nature of investment (inaction) and adjustment costs, but has not modeled heterogeneous investment decisions among observationally similar firms.¹² In practice, firms with similar attributes often invest very different amounts. We accommodate this by introducing v_{jt} that shifts the marginal cost of investment across firms. Note that v_{jt} can also explain inaction: firms with unfavorably large v_{jt} will choose not to invest. Once we allow for v_{jt} , additional adjustment costs, such as $\frac{i_{jt}^2}{k_{jt}}$ and/or a (random) fixed cost, contribute little to the model fit.¹³

Entry In each period t , $\bar{N}$ potential entrants observe the payoff relevant state variables and their private i.i.d. entry cost κ_{jt} before making a one-time entry decision. The entry cost is drawn from a distribution $F_\kappa(\kappa|s_{jt})$ that is shifted by industrial policy (which is part of the state variable s_{jt}). If potential entrant j decides not to enter, it vanishes with a payoff of zero. Otherwise, it pays the entry cost and continues as an incumbent in the next period. The entrant is assumed to be endowed with a random initial capital

¹²Notable exceptions include [Ryan \(2012\)](#) that models firm investment decisions as following an S-s rule and [Collard-Wexler \(2013\)](#) that analyzes discrete investment.

¹³The estimated fixed cost of investment is economically small and thus excluded. Fixed costs are associated with an inaction region where firms do not invest. The larger the fixed cost, the larger the inaction region. Firms do make small investments in our data, which is inconsistent with a large fixed cost.

stock that is realized the following period once the firm becomes an incumbent and begins operation.

Potential entrant j solves:

$$\max \{0, -\kappa_{jt} + \mathbb{E} [-C^i(k_{jt+1}, s_{jt}) + \beta \mathbb{E} [V(s_{jt+1})|s_{jt}]] \}$$

where κ_{jt} is the entry cost and k_{jt+1} is entrant j 's initial capital stock in period $t + 1$ after paying a cost of $C^i(k_{jt+1}, s_{jt})$. The expectation is taken over entrant j 's information set at time t , which includes all aggregate state variables.

Similar to the exit decision, the optimal entry policy is of the threshold form: a potential entrant enters the market if the entry cost κ_{jt} drawn is lower than the value of entering, i.e.

$$\kappa_{jt} \leq VE(s_{jt}) \equiv \mathbb{E} [-C^i(k_{jt+1}, s_{jt}) + \beta \mathbb{E} [V(s_{jt+1})|s_{jt}]]$$

Since κ_{jt} is random, the potential entrant enters with probability p_{jt}^e that is defined by:

$$p^e(s_{jt}) \equiv \Pr(\kappa_{jt} \leq VE(s_{jt})) = F_{\kappa}(VE(s_{jt})|s_{jt}) \quad (8)$$

Equilibrium A Markov-Perfect Equilibrium of this model consists of policies, $\{q_{jmt}^*\}_{m=1}^M$, $t^*(s_{jt}, v_{jt})$, $p^x(s_{jt})$, $p^e(s_{jt})$, value function $V(s_{jt})$ and prices P_{mt} , such that the production quantity satisfies (2) and maximizes the period profit, the exit policy satisfies (5), the investment policy satisfies (6), the entry policy satisfies (8), and ship prices clear the market each period so that aggregate ship demand equals aggregate supply. Moreover, the incumbent's value function satisfies (3) and firms employ the above policies to form expectations.¹⁴

Discussion We close this section with a brief discussion on our assumptions. We assume that ships are homogeneous within a type conditioning on size. To substantiate this assumption, we explore a subsample of new ship purchase contracts with detailed price information and ship attributes. Ship type, ship size in CGT, and quarter dummies explain most of the price variation: the R^2 of a hedonic price regression with only these regressors is 0.93 for bulkers, 0.94 for tankers, and 0.75 for containerships. Shipyard characteristics (age, country, number of docks and berths, etc.) have limited explanatory power: including shipyard fixed effects in the hedonic regressions adds little to the fit except for containerships where the R^2 increases moderately. On the ship buyer side (shipowners), monopsony power is not a first-order issue as the concentration among shipowners is low.

We assume away dynamic considerations in production. In practice, as producing a ship takes time, production today affects the backlog tomorrow, which affects tomorrow's operation costs and therefore production decisions. However, as documented in Kalouptsidei (2018) that allows for such dynamics, cost function estimates are similar under the static and dynamic model, especially when it comes to the

¹⁴The equilibrium existence follows from Ericson and Pakes (1995) and Doraszelski and Satterthwaite (2010).

estimated subsidies. This is partly because the drastic production expansion observed cannot be explained by inter-temporal considerations that arise with dynamic production. We allow backlogs to affect the marginal cost of production, which proxies for dynamic considerations in a reduced-form manner.

Cost shocks ω_{jmt} are i.i.d. There are several reasons for this choice. First, ω_{jmt} is estimated to be moderately persistent, with a serial autocorrelation of 0.28 for bulkers, 0.27 for tankers, and 0.39 for containerships. Second, while it is straightforward to estimate the persistence of these shocks using quantity choices (Section 4.1), incorporating a persistent time-varying unobserved state variable in a dynamic model raises considerable computational challenges. For the same reason, investment cost shocks v_{jt} are assumed i.i.d.

That said, our model does incorporate persistent effects through the backlog and capital stock. When firms experience favorable ω_{jmt} shocks, they increase orders and production and therefore backlog. Since backlog captures firms' production efficiency and is a state variable, firms with higher backlog invest more, which increases future capital stock and further lowers long-run production costs. This mechanism is the primary reason that ex-ante identical firms have different growth trajectories over time, as highlighted by [Ericson and Pakes \(1995\)](#).

Last, we follow the literature ([Ryan, 2012](#)) and assume that government policies are perceived as permanent by all firms. We assume that the equilibrium before and after the policy is stationary, given our rich set of state variables. Relaxing this assumption and estimating firms' expectations and adaptation to a changing environment is a difficult but important topic for future research ([Doraszelski et al., 2018](#); [Jeon, 2018](#)).

4 Estimation Strategy

The key primitives of interest are the world demand function for new ships, the shipyard production cost function, the investment cost function, the distribution of scrap values, and the distribution of entry costs. We estimate the heterogeneous production cost function for shipyards in all countries but only analyze dynamic decisions (entry, exit, and investment) for Chinese shipyards. This is because aggregate data suggest that entry, exit, and capacity expansion are limited in Japan and South Korea ([OECD, 2015, 2016](#)) and because we do not have firm-level data on dynamic decisions for shipyards outside China. We recover the magnitude of the (unobserved) subsidies by estimating the production, investment, and entry costs of Chinese firms before and after each period of government intervention and in comparison to other countries when possible.

This section is self-contained and the reader may omit it and proceed to the results section if desired. Section 4.1 discusses estimation of the static parameters (demand and production costs). Sections 4.2.1 and 4.2.2 present the first and second stage of estimating dynamic parameters: investment cost, scrap values, and entry costs. Appendices B.1 - B.3 provide more details on estimation. Appendix B.4 discusses in detail the identification and data variation that allows us to estimate the model.

4.1 Estimation of Static Parameters

Demand The demand curve (1) for ship type m is parameterized as follows:

$$Q_{mt} = \alpha_{0m} + \alpha_{pm}P_{mt} + d'_{mt}\alpha_{dm} + \varepsilon_{mt}^d \quad (9)$$

The demand shifters d_{mt} include freight rates, the total backlog of type m , and type-specific variables. Demand for new ships is higher when demand for shipping services is high, reflected in higher freight rates.¹⁵ Conversely, a large backlog implies that more ships will be delivered in the near future, which reduces demand for new ships today. We also control for aggregate indicators of economic activity relevant to each ship type: the wheat price and Chinese iron ore imports for bulk carriers, Middle Eastern refinery production for oil tankers, and world car trade for containerships. Some specifications include time trends. Finally, we allow the price elasticity to change before and after 2006, the main policy year.

Prices are instrumented by steel prices and steel production.¹⁶ Steel is a major input in shipbuilding and contributes to 25 - 30% of the variable production costs (Jiang and Strandenes, 2012). The identification assumption is that steel prices and steel production are uncorrelated with new ship demand shocks ε_{mt}^d after controlling for primary economic factors relevant to ship demand. This is a plausible assumption because only a modest portion of global steel production is used in shipbuilding and an increase in ship demand ($\varepsilon_{mt}^d > 0$) is unlikely to have an impact on steel prices.¹⁷ As there is a single global market for each ship type, the demand curves are estimated from time series variation.

Production Costs The marginal cost function $MC_m(q_{jmt}, s_{jmt}, \omega_{jmt})$ is defined as:

$$MC_m(q_{jmt}, s_{jmt}, \omega_{jmt}) = \beta_{0m} + s'_{jmt}\beta_{sm} + \beta_{qm}q_{jmt} + \omega_{jmt}$$

where q_{jmt} denotes tons of ship type m produced by firm j in period t . Because of time to build, there are differences between orders placed, deliveries, and production in a given period. We use orders as a measure of q_{jmt} because the number of tons ordered is the relevant quantity decision made by the firm and responds to observed ship prices. In addition, our data source reports orders and deliveries instead of production and it is not straightforward to infer production from orders.

Cost shifters s_{jmt} include firm j 's capital stock and its backlog of all ship types. Capital accumulates through investment over time and reduces production costs via economies of scale. Backlogs affect costs through either economies of scale (e.g. large input purchases or simultaneous production of multiple ships) or capacity constraints (Jofre-Bonet and Pesendorfer, 2003). In addition, s_{jmt} contains shipyard

¹⁵The freight rate measures are the Baltic Exchange Freight Index for bulk shipping, the Baltic Exchange Clean Tanker Index for tankers, and the Containership Timecharter Rate Index for containerships.

¹⁶While demand elasticities in principle affect production cost estimates, they have a modest effect in our setting largely because markups are modest. See Section 5.4 for details.

¹⁷Internationally traded steel accounts for less than 8% of the volume transported by bulk carriers (UNCTAD, 2018). Thus, changes in steel prices (which affect steel transported) are unlikely to affect demand for bulk carriers.

j 's age and ownership status, nationality and region (for Chinese firms), a dummy for large firms, the steel price, as well as polynomial terms of these state variables.¹⁸ Lastly, s_{jmt} includes dummies for the policy intervention between 2006 and 2008 and then from 2009 onwards. The production cost shock ω_{jmt} is assumed to be normally distributed with mean zero and variance $\sigma_{\omega m}^2$.

The first-order condition of firm j 's profit maximization problem is (allowing for zero quantity):

$$\begin{aligned} MR_{jmt} &\leq MC_m(q_{jmt}, s_{jmt}, \omega_{jmt}) \\ P_{mt} + q_{jmt} \frac{\partial P_{mt}}{\partial q_{jmt}} &\leq \beta_{0m} + s'_{jmt} \beta_{sm} + \beta_{qm} q_{jmt} + \omega_{jmt} \end{aligned}$$

Let $\bar{\beta}_{qm} = \frac{1}{\beta_{qm} - \bar{\alpha}_{pm}}$. The optimal quantity produced is characterized by the following equations:

$$\begin{aligned} q_{jmt}^* &= \bar{\beta}_{qm} (P_{mt} - \beta_{0m} - s'_{jmt} \beta_{sm} - \omega_{jmt}) \\ q_{jmt} &= \max\{0, q_{jmt}^*\} \end{aligned} \quad (10)$$

where q_{jmt} is firm j 's optimal production at time t .

The parameters characterizing shipyards' production costs are $\theta^q \equiv \{\beta_{0m}, \beta_{sm}, \beta_{qm}, \sigma_{\omega m}\}_{m=1}^M$. We estimate these parameters via a Tobit model:

$$L = \prod_{m=1}^M \prod_{j,t; q_{jmt}=0} Pr(q_{jmt} = 0 | s_{jt}; \theta^q) \prod_{j,t; q_{jmt}>0} f_q(q_{jmt} | s_{jt}; \theta^q)$$

Note that the MLE estimate of θ^q is consistent even if ω_{jmt} is correlated over time, despite the fact that the likelihood function assumes (erroneously) ω_{jmt} is i.i.d. (Robinson, 1982).¹⁹ To obtain the standard errors allowing for autocorrelation in ω_{jmt} , we use 500 (firm-block) bootstraps. Moreover, an implicit assumption of the Tobit estimation is that ω_{jmt} is independent of the price P_{mt} . This could be violated if favorable shocks lead to high production and affect ship prices. We allow ω_{jmt} to be correlated with P_{mt} in robustness analyses in Section 5.4.

Finally, a firm's production decisions provide no information on the fixed cost c_0 (costs of land usage, capital maintenance, etc.) since the firm incurs this regardless of whether it produces. Unlike most empirical studies where fixed costs are assumed away, we take advantage of the reported accounting cost data to calibrate c_0 (which existed even when the production facility is idle), see Appendix B.1. Restricting the fixed cost to zero may bias the counterfactual analyses (Aguirregabiria and Suzuki, 2014; Kalouptsi et al., 2021); we discuss this issue in Section 6.1.

¹⁸Large firms are defined as the set of firms that account for 90% of aggregate industry revenue in our sample period. Fifty-five Chinese shipyards are large. This variable (on top of capital and other firm attributes) captures unobserved differences across firms, like management skills and political connections, and improves model fit.

¹⁹Intuitively this is similar to how the OLS estimator in the standard linear regression model continues to be consistent (though not efficient) when the errors are non i.i.d.

4.2 Estimation of Dynamic Parameters

We use observed firm-level investment, entry, and exit to estimate dynamic parameters. An important complication is that firms' optimal choices depend on the value function (as well as unobserved cost shocks for investment), which is unknown. To tackle this challenge, we follow the tradition of [Hotz and Miller \(1993\)](#) and [Bajari et al. \(2007\)](#) (henceforth BBL) and estimate the parameters in two stages. In the first stage, we flexibly estimate investment and exit policy functions, as well as the transition process of state variables from the data. Then, we use these estimates to obtain a flexible approximation of the value function. We approximate the value function by a set of B-spline basis functions of state variables, following [Sweeting \(2013\)](#) and [Barwick and Pathak \(2015\)](#). In the second stage, we formulate the likelihood of the observed investment and exit and recover the dynamic parameters of interest.

4.2.1 First Stage

Exit Policy Function We perform a probit regression, though results are robust to alternative specifications:

$$Pr(\chi_{jt} = 1 | s_{jt}) = \Phi(h(s_{jt}))$$

where χ_{jt} equals 1 if firm j exits in period t , $h(s_{jt})$ is a flexible polynomial of the states, and Φ is the normal distribution. We denote the first-stage estimate of the exit probability by $\hat{p}^x(s_{jt})$.

Investment Policy Function The optimal investment policy function $i_{jt}^*(s_{jt}, v_{jt})$ is implicitly defined by the first order condition in equation (6). Our goal is to flexibly estimate $i_{jt}^*(s_{jt}, v_{jt})$. Under reasonable assumptions, one can show that the optimal investment is monotonically decreasing in v_{jt} : firms with more favorable (smaller) cost shocks invest more, all else equal.²⁰ As a result, conditioning on s_{jt} , the j^{th} quantile of v_{jt} corresponds to the $(100 - j^{th})$ quantile of i_{jt} . As shown in [Bajari et al. \(2007\)](#), we can recover the optimal investment policy function $i_{jt}^*(s_{jt}, v_{jt})$ as follows:

$$\begin{aligned} F(i|s_{jt}) &= Pr(i_{jt}^* \leq i | s_{jt}) = Pr(v_{jt} \geq i^{*-1}(s_{jt}, i) | s_{jt}) = Pr(v_{jt} \geq v | s_{jt}) \\ &= 1 - F_v(v | s_{jt}) = 1 - F_v(v) \\ \text{which implies } i^*|s_{jt} &= F^{-1}(1 - F_v(v)) \end{aligned} \tag{11}$$

where $F(i|s_{jt})$ denotes the empirical distribution of investment given the state variables and $F_v(v|s_{jt})$ is the distribution of v conditional on state variables. The data requirement for estimating this conditional distribution non-parametrically increases dramatically with the number of state variables. We make the simplifying assumption that the investment cost shock v_{jt} is independent of observed state variables s_{jt}

²⁰One sufficient condition for monotonicity is that the value function has increasing differences in investment and the negative of the investment shock.

and enters additively in the investment policy function:

$$i_{jt}^* = h_1(s_{jt}) + h_2(v_{jt}) \quad (12)$$

where both $h_1(s_{jt})$ and $h_2(v_{jt})$ are unknown functions to be estimated. Moreover, since the distribution of v_{jt} cannot be non-parametrically identified from $h_2(v_{jt})$, we assume that v_{jt} is drawn from a standard normal. We flexibly regress investment on state variables to obtain an estimate of $h_1(s_{jt})$. Then we treat $i_{jt}^* - \hat{h}_1(s_{jt})$ as the relevant data and estimate function $h_2(\cdot)$ using equation (11).²¹

State Space The vector of state variables s_{jt} is a high-dimensional object because of the large number of firms in the industry. To reduce the computational burden, we assume that firms do not keep track of the state variables of every rival and use industry-level prices as a sufficient statistic (our estimates in Section 5.1 suggest that market power is limited). This approach is similar to the oblivious equilibrium concept in Weintraub et al. (2008) and Benkard et al. (2015) that approximates the Markov Perfect Equilibrium in industries with many firms. These techniques have been utilized in many recent empirical papers.²²

We utilize the fact that a number of state variables enter the firm's marginal cost linearly and collapse them into a one-dimensional index, $\bar{s}_{jt} = -\sum_m s_{jmt} \hat{\beta}_{sm}$, using the estimated production cost coefficients. This index measures firms' observed cost efficiency: a higher $\bar{s}_{jt}$ is associated with a lower marginal cost and a higher variable profit.²³

State Transition Process Some state variables, such as the province and ownership status, are fixed over time. Age increases are deterministic. Capital (k_{jt}) depreciates at a common rate δ : $k_{jt+1} = (1 - \delta)k_{jt} + i_{jt}$. We calibrate δ to 2.3% quarterly (Brandt et al., 2012), reflecting China's high interest rates over our sample period. The steel price, which is perceived as exogenous to the industry, follows an AR(1) process. The equilibrium price for each ship type is a complicated object, determined by the aggregate demand and supply. We model ship prices as separate AR(1) processes, a behavioral assumption common in the literature (Aguirregabiria and Nevo, 2013). Government policies present a permanent and unanticipated shock to the industry, which potentially affects the evolution of prices. To capture this, we allow the AR(1) process for ship prices to differ before and after 2006 when the policies came into effect.

Value Function Approximation Armed with estimates of the policy functions and state transitions, we turn to the value function. The scrap value ϕ_{jt} is distributed exponentially with parameter $1/\sigma_\phi$. Hence,

²¹We drop 5% outliers with investments exceeding RMB 250 million or capital stocks exceeding RMB 4 billion. Appendix B.2 performs robustness checks using Tobit and the Censored Least Absolute Deviation estimator (CLAD).

²²See Huang et al. (2015), Sweeting (2015), Gerarden (2017), Jeon (2018) and Chen and Xu (2018).

²³Using type-specific cost indices $\bar{s}_{jmt} = -s_{jmt} \hat{\beta}_{sm}$, $m = 1, 2, 3$ instead of one index $\bar{s}_{jt}$ leads to similar dynamic parameter estimates. This is because firms that are better at producing one ship type are generally better at producing other ship types as well, and $\bar{s}_{jt}$ (with other state variables) approximates the value function well. See Appendix B.3.

the ex-ante value function (prior to the realization of ϕ_{jt}) is:

$$\begin{aligned} V(s_{jt}) &\equiv \mathbb{E}_\phi V(s_{jt}, \phi_{jt}) = \mathbb{E}_\phi [\pi(s_{jt}) + \max\{\phi_{jt}, CV(s_{jt})\}] \\ &= \pi(s_{jt}) + p^x(s_{jt}) \mathbb{E}(\phi_{jt} | \phi_{jt} > CV(s_{jt})) + (1 - p^x(s_{jt})) CV(s_{jt}) \\ &= \pi(s_{jt}) + p^x(s_{jt}) \sigma_\phi + CV(s_{jt}) \end{aligned} \quad (13)$$

where $\mathbb{E}(\phi | \phi > CV) = \sigma_\phi + CV$ (Pakes et al., 2007). $\pi_{jt}(s_{jt})$ and $p^x(s_{jt})$ denote firms' static profit and exit probability, respectively, and $CV(s_{jt})$ denotes the firm's continuation value as defined in equation (4). We use B-spline basis functions to approximate the ex-ante value function, a smooth function that in theory can be approximated arbitrarily well (see further details in Appendix B.3).

4.2.2 Second Stage

Investment and Exit The dynamic parameters are $\theta^i \equiv \{\sigma_\phi, c_1, c_2, c_3\}$. We allow the linear component of investment costs, c_1 , to differ before and after every policy period to capture the investment subsidies. We estimate θ^i via MLE, where the sample likelihood includes the likelihood for both exit and investment decisions. The log-likelihood for exit is:

$$\sum_{j,t} \log(f(\chi_{jt})) = \sum_{j,t} \left[(1 - \chi_{jt}) \log(1 - e^{-\frac{CV(s_{jt}; \gamma)}{\sigma_\phi}}) - \chi_{jt} \frac{CV(s_{jt}; \gamma)}{\sigma_\phi} \right]$$

where $\chi_{jt} = 1$ if firm j exits in period t .

Optimal investment $i_{jt}^* = i^*(s_{jt}, v_{jt})$ is defined by the first order condition in (6). By construction, when $i^*(s_{jt}, v_{jt})$ is positive, it is strictly monotonic in v_{jt} . Assuming it is also differentiable, the likelihood of investment can be written as:²⁴

$$g(i_{jt}) = \begin{cases} \frac{f_v(v_{jt})}{|i'(v_{jt})|} & \text{if } i^*(s_{jt}, v_{jt}) > 0 \\ Pr\left(\left[\beta \frac{\partial \mathbb{E}(V(s_{jt+1}; \gamma) | s_{jt}, i)}{\partial i} - \frac{\partial C^i(i, s_{jt}, v_{jt})}{\partial i}\right]_{i=0} \leq 0\right) & \text{if } i^*(s_{jt}, v_{jt}) \leq 0 \end{cases}$$

where in the first row, $f_v(v_{jt})$ is the density of cost shock v_{jt} and $|i'(v_{jt})|$ is the absolute value of the derivative of $i^*(s_{jt}, v_{jt})$ with respect to v_{jt} .

Since the scrap value ϕ_{jt} and investment shock v_{jt} are assumed independent, the joint log-likelihood for exit and investment is the sum of the two respective log-likelihoods. We maximize the sample log-likelihood subject to the Bellman equation (13):

²⁴The necessary condition for differentiability is that the value function is twice differentiable in investment, which holds since the value function is approximated by smooth spline basis functions.

$$\begin{aligned} \max_{\theta^i} L &= \sum_{j,t} \log(f(\chi_{jt}; \theta^i)) + \sum_{j,t} \log(g(i_{jt}; \theta^i)) \\ \text{s.t. } V(s_{jt}; \theta^i) &= \pi(s_{jt}) + p^x(s_{jt})\sigma_\phi + CV(s_{jt}; \theta^i) \end{aligned} \quad (14)$$

Entry Cost Parameters We assume that entry costs are exponentially distributed. Estimating the mean of entry costs is straightforward once the investment cost and scrap value parameters are known. Upon entry, an entrant is endowed with capital that is drawn from the observed distribution of initial capital stocks. The cost of the initial capital equals $C^i(k_{jt+1}, s_{jt}) = c_1(s_{jt})k_{jt+1}$, which is the same as the cost of investment, except that there are no adjustment costs. We first construct the value of entry $VE(s_{jt})$ by plugging in dynamic parameter estimates and then estimate the mean entry costs using equation (8) via MLE. We do this separately before and after each policy period for each region, in order to capture the effect of entry subsidies (which differ across regions) that shift the mean of the entry cost distribution.

5 Results

This section follows closely the sequence in Section 4. Section 5.1 presents results on static parameters (demand and production costs). Section 5.2 discusses policy functions and the state transition process. Section 5.3 reports dynamic parameter estimates (investment cost, scrap values, as well as entry costs). Section 5.4 evaluates robustness. All costs (production costs, investment costs, and entry costs) are in real terms and measured in 2000 RMB. Appendix C provides more details.

5.1 Static Parameters

Demand Table C4 reports estimates of the demand curve (9). All variables have the expected sign and the effects are significant both economically and statistically. For example, demand for all ship types increases with freight rates. Demand is also responsive to backlog (which affects the future competition that shipowners face): a 1% increase in the backlog leads to a 1% decrease in the quantity of new ships demanded. According to our preferred specification (Column 2), the price elasticity was 1.8 for bulk carriers and tankers, 3.4 for containerships prior to 2006 and became somewhat less elastic afterwards.²⁵

Production Costs Table 2 shows the estimated marginal cost parameters for Chinese yards for each ship type (standard errors are computed from 500 firm-block bootstrap simulations). Marginal costs are measured in 1000 RMB per CGT. The key parameters that characterize the curvature of production cost are type-specific (the coefficients on quantity, capital, backlog, and steel price), but coefficients on

²⁵Note that our preferred specification in Column 2 does not include a trend, which would make the dynamic model non-stationary.

subsidy dummies and shipyard attributes are restricted to be the same across ship types to reduce the number of parameters. There are intuitive reasons for these restrictions. The benefit of scale economies from holding a large backlog, the return to capital (which proxies for capacity), and input intensity are likely to be different across ship types. On the other hand, the effect of subsidies on production costs is probably similar across types, as subsidies are not earmarked by ship type, and firms can produce different ships depending on prevailing market conditions.

As China's policies came into effect in 2006 and underwent major changes in 2009, we allow production subsidies to be different between 2006-2008 and from 2009 onwards. The production subsidy is estimated to be 2,100 RMB/CGT between 2006-2008, which is 14-18% of the average price. The subsidy from 2009 onwards is smaller, at 1,220 RMB/CGT.²⁶ Though our estimation method, sample period, and industry coverage are different from Kalouptisidi (2018), the estimated subsidy is of a similar magnitude (with ours being slightly smaller), which is reassuring. Robustness exercises in Section 5.4 suggest that subsidy estimates remain similar in a DID framework that compares China to its competing countries and are robust to additional controls and different sample cuts, alleviating the concern of confounding factors that affect the industry cost structure. Although this approach of estimating subsidies has its own caveats, it is likely the only feasible strategy next to observing the subsidies directly.

The parameter β_q captures the increase in marginal cost (in 1000 RMB/CGT) from taking an additional order of 100,000 CGT. The larger β_q is, the more convex the cost function is, and the less responsive supply is to price changes. On average, a 10% price increase causes bulk carrier production to increase by 22%, tanker production by 27%, and containership production by 20%. Higher capital is associated with a lower marginal cost of production, though at a diminishing rate (the coefficient on capital squared is positive). Increasing capital by RMB 100 million for an average firm with a capital of RMB 400 million reduces marginal cost of production by 2.7% for bulkers, 2.2% for tankers, and 2.2% for containerships. To put these numbers into context, the average firm's per-period profits would decline by 19% if its capital stock were halved.

There are economies of scale in production with respect to the backlog: it is cheaper to produce multiple ships at the same time. The effect of backlog on marginal cost is sizable: increasing backlog by 100,000 CGT reduces marginal cost of production by 13% to 30% on average across ship types. As backlogs continue to increase, capacity constraints drive up marginal costs, as reflected in the positive coefficient (though smaller in magnitude) on backlog squared. Firms located in Jiangsu, Liaoning, and Zhejiang provinces (the major shipbuilding regions) have lower marginal costs, by 20-26% for Jiangsu, 14-18% for Liaoning, and 11-14% for Zhejiang. As shipyards age, their marginal cost increases by 1% each year. The effect of ownership is limited and statistically insignificant. Increases in steel prices raise marginal costs for all types, as expected.

Market power distortions are limited. The average markup for bulk carriers is 6.39% of new ship

²⁶Strictly speaking, these estimates reflect the pre- and post-2006 differences in subsidies. Our understanding is that production subsidies prior to 2006 were limited. Labor costs in China's manufacturing industry have been rising during the sample period (source: https://www.bls.gov/fls/china_method.htm). Controlling for labor costs leads to similar though slightly bigger subsidy estimates, reflecting the modest cost share of labor at around 10-20%.

prices and even lower for tankers and containerships. As a result, firms' production decisions are not far from setting marginal cost equal to the market price, suggesting that the industry is close to competitive.

Finally, the fixed cost calibrated from accounting data equals RMB 15 million per quarter, equivalent to 12% of the industry profit on average. Hence, setting it to zero, as is commonly done in the literature, would significantly overestimate per-period profits accruing to firms.

5.2 Dynamic Parameters: First Stage

Investment Policy Function Table C5 reports estimates for the investment policy function using OLS, Tobit with $h_2(v)$ normally distributed, and the Censored Least Absolute Deviation estimator that does not impose a distributional assumption on the cost shock and estimates $h_2(v)$ non-parametrically. Our preferred specification is OLS, which delivers the highest model fit. Investment increases in ship prices and decreases in steel price. Firms with higher $\bar{s}_{jt}$ (more productive) invest more all else equal. As expected, coefficients for both the 2006-08 and 2009+ policy dummies are positive. Moreover, investment is hump-shaped in the capital: it initially increases in capital stock, reaches a peak when capital is between RMB 1-1.5 billion, and then falls.

Exit Policy Function We estimate the exit policy function via Probit. Table C6 presents two sets of estimates using linear terms of all states as well as capital squared, with and without region fixed effects. Firms with higher $\bar{s}_{jt}$ are less likely to exit, which is intuitive as $\bar{s}_{jt}$ is a measure of firm profitability. Exit probabilities are lower when subsidies are in place.

5.3 Dynamic Parameters: Second Stage

Investment and Exit Table 3 reports the investment cost estimates.²⁷ Between 2006-2008, the subsidy was 0.27 RMB per RMB of investment, implying that 27% of the per-unit cost of investment (excluding adjustment costs) is subsidized. Post 2009, the subsidy jumps to 0.46 RMB per RMB of investment, which helps rationalize the elevated investment post the financial crisis with plummeting ship prices. In addition, the increase in subsidies post 2009 is consistent with the government policy change that shifted the focus towards consolidating the industry and supporting existing firms.

The coefficient on quadratic investment, c_2 , is both economically and statistically significant. On average, adjustment costs account for 28% of total investment costs and exceed 50% for large investments over RMB 50 million. The large estimate of c_3 reflects the importance of firm-level unobserved investment shocks. Finally, average scrap value is estimated to be RMB 0.98 billion. This is significantly lower than the estimated value of a firm, $V(s_{jt})$, which is around three to four billion RMB, as exit is a rare event and occurs in only 1% of the observations.

²⁷The linear investment cost coefficient is equal to $c_1(s_{jt}) = 1 + \gamma_1 * 1\{2006 - 2008\} + \gamma_2 * 1\{2009+\}$, where we assume that the unit investment cost is equal to 1, following the empirical literature on investment (Cooper and Haltiwanger, 2006). Monte Carlo evidence indicates that it is difficult to identify this parameter.

Figure C3 plots the distribution of the observed and model-predicted investment. They are reasonably similar, though actual investment has a longer tail of large investments and fewer medium-sized ones. Table C8 compares the actual number of exits with the model’s estimates. Firm exits are low-probability events and in general difficult to predict (Goldfarb and Xiao, 2016). Our model roughly matches the sample mean but under-predicts the number of exits post 2006.

Entry Cost Estimates The number of entrants is quite different across provinces, with Zhejiang having the highest number of entrants at 95 during the sample period and Liaoning, Jiangsu, and Zhejiang collectively accounting for 70% of new shipyards. We estimate the entry cost separately for Liaoning, Jiangsu, Zhejiang, and the rest of China.²⁸ We also allow the entry cost to differ across policy periods. Table 4 reports estimates for the mean entry costs for period before 2006, between 2006 and 2008, and post 2009 respectively. In light of the unprecedented entry boom from 2006 to 2008, it is unsurprising that we find substantial entry subsidies, with the fraction of entry costs that is subsidized varying from 51% in Liaoning to 64% in Jiangsu. Entry costs increased substantially in 2009 when the entry moratorium was put in place. Conditional on entering, the average entry cost paid is RMB 2.5 billion, close to a shipyard’s accounting value.²⁹ Our estimated number of entrants is reasonably close to the actual number in each policy period (Table C9).

5.4 Robustness

The baseline specification estimates production costs separately for each country. Table C11 pools shipyards from all three countries, which amounts to a DID estimator. As we do not observe capital for Japanese and South Korean shipyards, we set their capital stock to zero and add country dummies. Results are qualitatively similar to the baseline, though the 2006-08 subsidy is somewhat larger. We prefer the baseline specification, which allows more flexibility in capturing production differences across countries and delivers a more conservative estimate of the subsidy magnitude.³⁰

Next, we explore whether there is evidence of learning-by-doing among Chinese shipyards (Benkard, 2004). We examine both within-firm and industry-wide learning-by-doing by allowing the marginal cost of production to depend on firms’ past production and industry cumulative past production. The results are presented in the second and third panels in Table C11. There is no evidence of either type of learning-by-doing: marginal costs tend to increase rather than decrease in past production. This is consistent with industry reports that the technology for producing bulk carriers and tankers has been around for decades and is mature. Past studies documenting learning-by-doing in shipbuilding (Thompson, 2001; Thornton and Thompson, 2001; Hanlon, 2020) provide mixed evidence on learning spillovers across

²⁸Entry subsidies are assumed to begin in 2004 for Zhejiang, when it identified shipbuilding as a pillar industry, and in 2006 for all other provinces. The observed entry peaked earlier in Zhejiang than the rest of the country.

²⁹The average entry cost conditional on entering is given by $\mathbb{E}(\kappa_{jt} | \kappa_{jt} \leq VE(s_{jt}))$. See <http://www.jiemian.com/article/1483665.html> and http://www.wuhu.com.cn/compay_mod_file/news_detail.php?cart=3&id=595 for news articles that report the book value of shipyards.

³⁰Using cost estimates that pool data from all three countries leads to qualitatively similar counterfactual results.

firms. [Thompson \(2001\)](#) attributes half of the previously documented learning-by-doing in US naval shipyards during the World War II to capital expansion, while [Thornton and Thompson \(2001\)](#) show that the size of learning externalities among these shipbuilders is small.

Incorporating a time trend or excluding new shipyards that entered after the policy announcement (which might have newer and better technologies) leads to similar results (Table C12). We have estimated production subsidies separately for each region. They are higher in Jiangsu and Liaoning than in Zhejiang and the rest of China, although the differences are statistically insignificant. While in principle production cost estimates depend on demand elasticity, in our setting they are robust to demand parameters largely because markups are modest.

The production analyses so far assume that firms' production cost shocks are independent of ship prices. This could be violated if favorable shocks lead to high production and affect ship prices. In Appendix C.5, we deal with this endogeneity problem by allowing the cost shocks to be correlated with ship prices and using a control function approach ([MacKinnon and Olewiler, 1980](#); [Smith and Blundell, 1986](#); [Newey, 1987](#); [Chernozhukov et al., 2015](#)). The cost estimates are similar to our baseline results. Moreover, the estimated correlation between production cost shocks and residuals of prices (after partialling out controls) is small and varies between 0.002 and 0.05 in absolute value across ship type. These results suggest that the rich aggregate controls in our cost specification minimize the potential for correlation.

A common challenge in estimating entry costs is that the number of potential entrants $\bar{N}$ is inherently unobserved. Our baseline assumes that the number of potential entrants in a region in any quarter is twice the maximum number of observed entrants in that region, following the literature ([Seim, 2006](#)). We have estimated the entry cost under alternative assumptions (e.g. the maximum number of entrants ever observed, or a large number such as 20 and 40). While a higher number of potential entrants leads to a higher estimate of κ_{jt} , the estimated entry cost paid upon entering and entry subsidies are remarkably robust as they are determined by the actual number of entrants and the value of entry (which is estimated using observed ship prices and firm production). Finally, Appendix Section B.3 and Section C report more details and additional robustness analyses.

6 Evaluation of China's Industrial Policy in Shipbuilding

Like other countries that use industrial policies to promote specific sectors ([Krugman et al., 1983](#); [Lane, 2022](#)), China adopted a variety of policy instruments to boost the shipbuilding industry's output. Moreover, the policy implementation underwent significant changes over time. Early on, subsidies were widely accessible to all firms. In later years, the government shifted support towards SOEs and established firms (the White List), while curbing the entry of new firms.

In this section, we evaluate the long-term implications of China's industrial policy. Our goal is to assess the relative performance of different policy instruments, taking into account the critical role played by firm heterogeneity, dynamics and business cycles. Specifically, we address the following questions:

(i) which policy instruments are the most effective; (ii) how should industrial policy be designed in the presence of industry fluctuations and business cycles; (iii) what are the consequences of targeting subsidies toward selected firms through consolidation policies?

Evaluating the industrial policy's long-term impact necessitates simulating the world shipbuilding industry for a long period of time, as both entry and investment have dynamic consequences – the accumulated capital remains productive long after the policy ends.³¹ Our simulation begins in 2006, when the Chinese government started subsidizing its domestic industry, and ends in 2050, a period long enough to evaluate a policy's dynamic impacts, though results are similar if longer horizons are used. In each counterfactual scenario, we turn on and off the subsidies as needed and report the industry average over 50 independent simulations (results are nearly identical with 100 simulations). Chinese firms make production, investment, exit, and entry decisions. Japanese and South Korean firms choose production. Equilibrium prices are determined by the intersection of the industry demand and supply curves. All monetary values, including industry revenues and total subsidies, are discounted (at a quarterly rate of 2%) and measured in the 2000 constant RMB.

Section 6.1 quantifies how the policy affected the actual evolution of the global industry between 2006 and 2013. Section 6.2 assesses the long-term performance of different policy instruments. Section 6.3 discusses various aspects of policy design, such as the timing of subsidies, targeting, and policy duration. Appendices D.1 and D.2 contain more details on implementation and Appendix D.3 reports additional counterfactual results.

6.1 Impact on Industry Evolution

Perhaps not surprisingly, the Chinese government's subsidies had a significant impact on the evolution of every outcome of interest: China's market share, total ship production, ship prices, entry and exit, investment, profits, industry concentration and capital utilization.

According to our estimates, total (discounted) subsidies handed out to Chinese shipbuilders between 2006 and 2013 were close to RMB 624 billion (\$91 billion), which can be broken down into entry subsidies (RMB 431 billion), production subsidies (RMB 156 billion) and investment subsidies (RMB 37 billion).³² These subsidies are massive in comparison to the size of the domestic industry, whose revenue was around RMB 1360 billion during the same period.

Government support increased China's world market share during 2006-13 by 42%. The ascent in market share is most pronounced for bulk carriers, since a large fraction of new shipyards produce bulk carriers, and Japanese and South Korean firms' cost advantage is narrower for bulk.

In absolute terms, only 30% of China's increased production translated into higher world output. The remaining 70% constitutes business-stealing, whereby Chinese production expanded at the expense

³¹Production subsidies also have dynamic consequences through backlogs that affect future costs of production, though these effects disappear within a few years when backlogs are converted to deliveries.

³²While entry subsidies are large in magnitude, they are consistent with a back-of-the-envelope calculation: entry subsidies induced the entry of 80 additional firms and each firm is worth a few billion RMB.

of competing firms in other countries. Chinese subsidies reduced South Korea's world market share from 48% to 39% and Japan's market share from 23% to 20% during 2006-2013, with profits earned by shipyards in these two countries falling by RMB 144 billion. Despite the rising market share of Chinese shipyards, their gains in gross profit (revenue minus production costs) in this period are a modest RMB 153 billion, as the output expansion was largely fueled by the entry of inefficient firms.

The subsidy-induced rising global supply led to a substantial reduction in global ship prices: the price of bulk carriers, oil tankers, and containerships fell by 9.9%, 10.1%, and 4.3% from 2006 to 2008, respectively (Table D14). As the impact of past subsidies accumulated over time, the price drop became more pronounced post 2009 and reached 16.8% for bulk carriers, 14.8% for tankers, and 4.2% for containerships. The price effect is the most significant for bulk carriers because Chinese shipyards account for a bigger market share and demand for bulk carriers is less elastic. Lower ship prices benefited world shipowners by RMB 290 billion, though only a modest amount accrues to Chinese shipowners as they account for a small fraction of the world fleet.³³

Figure 2 illustrates the striking effect of subsidies on investment, which skyrocketed post 2006. Total investment during 2006-2013 is RMB 80 billion with subsidies, compared to RMB 33 billion without subsidies. Figure 3 examines the effect on the number of Chinese firms. Government support more than doubled the entry rate: 143 firms entered with subsidies vs. 64 without subsidies from 2006 to 2013. It also depressed exit (38 firms exited vs. 43 without subsidies).

Finally, the policy led to increased fragmentation. Entry subsidies induce entry of small inefficient firms. Production and investment subsidies boost firms' variable profit and retain unprofitable firms that should have exited. China's domestic Herfindahl-Hirschman index (HHI) plummeted from 1,200 in 2004 to less than 500 in 2013 with a significantly lower 4-firm concentration ratio (Figure D4). Despite a sizable increase in China's overall production, capacity utilization was much lower, particularly when demand was low post 2009. If China had not subsidized the shipbuilding industry, the ratio of production to capital (which proxies for capacity utilization) would have been 19% higher during the 2009-2013 recession.

6.2 Long-term Performance of Policy Instruments

We carry out five counterfactual exercises with different subsidies in place: all subsidies (as in the data), only production subsidies, only investment subsidies, only entry subsidies, and no subsidies. We assume that the 2013 policy environment is propagated to the end of our simulation period. For example, in the scenario with all subsidies, entry subsidies run from 2006 to 2008, whereas production and investment subsidies run from 2006 to 2050. Since China's domestic consumer surplus is modest compared to the industry profit as discussed earlier, we focus on industry outcomes, such as output and profits, in our discussion below.³⁴

³³Orders by Chinese shipowners were growing but accounted for under 10% of world orders in 2010-2013 (Clarkson World Shipyard Monitor).

³⁴Incorporating consumer surplus enjoyed by Chinese shipowners increases the gross rate of return from 18% to 24%.

Table 5 reports the discounted sums of long-term industry revenue and profit for Chinese shipyards, as well as the magnitude of different subsidies. The last two rows, “ Δ Revenue/Subsidy” and “ Δ Net Profit/Subsidy”, constitute different measures of policy effectiveness. “ Δ Revenue” is the revenue difference between the scenario with subsidies and the scenario without subsidies. The ratio between increased revenue and subsidy cost reflects a policy’s effectiveness on promoting industry revenue. This is of interest, as China’s official government documents explicitly state production targets for the domestic ship-building industry. “ Δ Net Profit” is the difference in net profit which equals revenue plus the scrap value upon exiting, minus the costs of production, investment, and entry. “ Δ Net Profit/Subsidy” measures the gross rate of return. A rate lower than 100% indicates that the cost of subsidies exceeds the net benefits to the domestic industry.³⁵

Comparison of Different Policy Instruments When all subsidies are in place, the policy mix is highly ineffective, as reflected by the rate of return being merely 18%. When each policy is in place in isolation, the return is 50% for production subsidies, 74% for investment subsidies, and 32% for entry subsidies, respectively. Thus, entry subsidies are substantially less effective than production and investment subsidies (more on this below). In addition, the distortions induced by multiple subsidies are convex: the combination of all policies yields a considerably lower return compared to each policy in isolation. Entry subsidies lower the entry threshold and thus attract inefficient entrants. With the introduction of production and investment subsidies, the number of firms in operation is further inflated due to subsidized revenue. This drives down the rate of return and makes the subsidies more distortionary in per-RMB terms.

An important factor contributing to the low returns is fixed costs. Firms incur fixed costs to stay in business even when they receive no orders from buyers. In volatile industries with cycles of booms and busts, this tends to be a common occurrence: firms are willing to suffer temporary losses and stay idle in anticipation of higher demand in the future (hysteresis). If fixed costs were zero, the rate of return on subsidies would increase from 18% to 25%.

We now turn to the performance of each type of subsidy in isolation. If industry revenue is the object of interest, both production and investment subsidies are effective. One RMB increase in either subsidy raises the industry’s revenue by 1.5 RMB. This might justify the popularity of these subsidies in China, since quantity and revenue targets are often linked to local officials’ promotions (Jin et al., 2005). Investment subsidies appear less distortionary than production subsidies (74% vs. 50%). Investment subsidies lead to a higher level of capital formation and facilitate long-term industry growth, while production subsidies have a more immediate impact on output (Table D15.)

Entry subsidies are the least effective policy instrument among the three by a large margin. They predominantly attract small and high-cost firms that would not find it profitable to enter in the absence of

³⁵The calculation here does not consider the cost to finance these subsidies. Estimates from Ballard et al. (1985) suggest that collecting 1\$ of government revenue costs \$0.17-\$0.56 in the U.S. Including the cost to finance subsidies further drives down the rates of return. Another issue is that some “subsidies”, such as simplification of the entry procedure, might not be financial. Appendix D.3 shows that this has a modest impact on policy returns.

subsidies (Table 2 shows that entrants, which are small in scale, are less efficient). In addition, the take-up rate for production and investment subsidies is much higher among firms that are more efficient: 82% of production subsidies and 68% of investment subsidies is allocated to firms that are more efficient than the median firm, whereas only 49% of entry subsidies goes to more efficient firms (Table D16). Furthermore, production and investment subsidies increase backlogs and capital stocks that lead to economies of scale and drive down both current and future production costs, a mechanism that is absent in entry subsidies.

The conclusion that entry subsidies are wasteful is driven by the observed data patterns. In addition to entrants being less efficient producers, compared to firms that existed before 2005, new entrants were more likely to be idle (74% vs 56%) and less likely to make investments (61% vs 72%). Many of these shipyards exited the market after the financial crisis. The number of active shipyards in China declined by almost 50% from its peak in 2009 to 2020 (Figure D5).

6.3 Policy Design

In this section, we turn to policy design and search for general lessons that can be applied in contexts outside China's shipbuilding industry, including counter-cyclical policies, filtering inefficient firms, and setting policy duration.

Business Cycles and Industrial Policy Like many other manufacturing industries, cycles of booms and busts are a fundamental feature of shipbuilding.^{36,37} To explore whether the effectiveness of subsidies varies over the business cycle, we carry out two counterfactuals. The first subsidizes production and investment during the 2006-08 boom, while the second subsidizes production and investment during the 2009-13 bust. All subsidies are discontinued afterwards. The subsidy rates are calibrated so that government spending is identical in both scenarios.

Strikingly, subsidizing firms during the boom leads to a net return of only 38%, whereas subsidizing firms during the downturn leads to a much higher return of 70%, as shown in Table 6. What explains this large difference?

There are two main contributing factors to this finding: convex production and investment costs, and firm composition. In boom periods, the industry is operating close to full capacity. Further expansion is costly and entails the utilization of high-cost resources. Firms that are already producing and investing may choose to engage in more rapid expansion than is optimal, incurring large adjustment costs. During a bust, on the other hand, the industry operates well below capacity and many production facilities remain

³⁶The macro and public finance literature that explores optimal fiscal policies over the business cycle generally recommends counter-cyclical fiscal policies, in order to smooth out intertemporal consumption (Barro, 1979), reduce the efficiency costs of business cycle fluctuations (Gali et al., 2007), and increase long-term investment by lowering volatility (Aghion et al., 2014). It is less well-understood, however, how industrial policy should be designed in the presence of industry fluctuations.

³⁷Business cycles themselves are not major causes of inefficiency. The subsidy return is slightly higher (23%) in Table D17 that uses the steady-state aggregate demand, compared to 18% in the baseline with a pronounced boom and bust cycle. This is because we control for the business cycles and aggregate demand shifters in simulations. The booms and busts only modestly exacerbate the low return due to the convexity of production and investment costs.

idle. Subsidies mobilize underutilized facilities, resulting in smaller distortions. The second contributing factor is the changing firm composition over the business cycle. Subsidies during a boom attract inefficient firms, which pushes down the rate of return. Figure 4 plots the average marginal cost index over time for both scenarios. Marginal costs are higher when subsidies are distributed during the boom than during the bust, as expected.

Despite the benefits of a counter-cyclical policy, the actual policy mix was overwhelmingly pro-cyclical: 90% of total subsidies was handed out between 2006 and 2008 vs. 10% between 2009 and 2013. This echoes a more general finding in the literature showing that developing countries typically use pro-cyclical fiscal policies (Frankel et al., 2014), due to budget constraints and political considerations (Tornell and Lane, 1999; Barseghyan et al., 2013).

Targeting Efficient Firms To facilitate consolidation and create firms that can compete against international conglomerates, China implemented *Shipbuilding Industry Standard and Conditions* in 2013 and periodically announced a list of firms that meet the industry standard, the “White List”. We next evaluate whether and to what extent the consolidation policy and targeting improves the return of subsidies, as well as the government’s actual choices of firms on the White List.

The first official White List consisted of 56 firms.³⁸ In our counterfactual exercise, we rank firms based on expected variable profits ($E[\pi_{jt}]$) in 2013, select 56 firms with the highest profitability to form the “optimal White List,” and simulate the industry from 2014 to 2050. These firms receive production and investment subsidies, while other firms receive no subsidies post 2013. We compare this policy to a scenario that subsidizes all firms after 2013 and one with no subsidies.

As shown in Table D18, directing subsidies towards the best set of firms (the optimal White List) generates *considerable* gains. The net rate of return for targeted production and investment subsidies is 71%, whereas the return is 37% when all firms are subsidized. This pattern holds across both measures of policy effectiveness (revenue and net profit), due to several reasons. First, subsidizing all firms encourages sub-optimal entry, while the White List policy only subsidizes existing firms and does not distort entry. Second, firms on the White List have lower production costs; shifting support to more efficient firms reduces misallocation. Third, these firms are less prone to sub-optimal investment and production decisions than the average firm in the presence of subsidies.

China’s actual White List appears to favor SOEs: 65% of firms selected by the government are SOEs, while 55% of our selected firms are SOEs. Out of the 56 firms chosen by the government, only 31 firms appear on our White List. Information asymmetries and regulatory capture might have biased the process in favor of interest groups (Lane, 2022).

Temporary Subsidies Our analyses above assume that the production and investment subsidies were long-term, as the subsidy program had no official end date and is still ongoing in some format today (e.g. shipbuilding was included in the latest program, “Made in China 2025”). Here, we examine how

³⁸We focus on 56 firms because four out of sixty firms on the 2014 White List cannot be matched to our datasets.

the policy would have performed if it were explicitly temporary in nature. We consider two types of policies: (i) a temporary policy where the government commits to phasing out subsidies by an end date T that is known to all firms; and (ii) a temporary targeted policy where the subsidies are temporary and targeted towards productive firms. This is similar to the “White List” policy that we examine above, but the subsidies are now temporary in nature. We contrast both policy designs against a permanent policy and the no-policy scenario, holding the government budget fixed among the three policies with subsidies.

We exclude entry subsidies, which are inefficient according to our analyses. Moreover, we implement these counterfactuals under a steady state demand. This is done on purpose to avoid the complications of whether the temporary subsidies coincide with a period of growth or recession, a topic that we examine in Section 6.2. Examining the effect of temporary subsidies introduces the methodological challenge that firms’ value functions are non-stationary. Appendix D.2 describes how we address this.

Table 7 compares these three alternative policy designs. The rate of return on permanent industrial policy is 47%.³⁹ In contrast, making industrial policy temporary results in a higher rate of return at 55%. Temporary industrial policy that is *targeted* towards productive firms results in the highest rate of return at 75%. Two mechanisms make temporary industrial policy more effective: a selection effect and a scale effect; temporary and targeted policy further magnifies these two channels. Permanent subsidies encourage entry, discourage exit, overprotect inefficient firms, and result in a fragmented industry structure. Making subsidies temporary dampens these negative selection effects. Second, temporary policies entail larger subsidies per unit of production and thus augment the increasing returns to scale and lead to a much higher backlog per firm. As a result of these two channels, the average firm is significantly more cost-efficient, especially under the temporary and targeted policy, in both the medium-term and long run (Figures D6 and D7).

We also investigate the optimal duration of a temporary policy (Table E19). The rate of return is not always monotonically increasing as the horizon is shortened. A short-lived policy performs poorly, with little capital accumulation due to convex costs of investment. The optimal horizon in our context is between 3 and 5 years. In comparison, the actual policy implemented in China lasted more than a decade, although it underwent significant changes over time.

Summary Our results shed light on the underlying mechanisms for diverging outcomes across countries due to the timing of intervention, choice of policy instruments, the discriminatory nature of the policy, and policy duration. For instance, in East Asian countries where industrial policy is often regarded as successful, policy support was conditioned on performance, with non-performing firms penalized by the withdrawal of support. In contrast, in Latin America where the import-substitution policies were less effective and abandoned in the 1980s, there were no effective mechanisms to weed out non-performing beneficiaries (Rodrik, 2009).⁴⁰ Our analysis highlights that similar mechanisms are at work in China’s

³⁹As this policy does not include entry subsidies, the return is substantially higher than the rate of return on the policy mix that China actually adopted (18%).

⁴⁰Lack of policy evaluations in Latin American countries is a significant hindrance to this debate (Peres, 2013).

modern-day industrial policy in the shipbuilding industry. The policy's return was low in earlier years when output expansion was primarily fueled by the entry of inefficient firms, but increased over time as the government shifted support to more efficient firms and used 'performance-based' criteria (the White List) to channel subsidies.

A key insight from our analysis is that industrial policy is relatively more effective when it takes into consideration firm heterogeneity and the nature of business cycles, prioritizing support for efficient firms at times when economic expansion is not costly. Investment subsidies outperform entry subsidies in part because they are mostly taken up by more efficient firms that dominate investment activity. Similarly, counter-cyclical policy mobilizes underutilized resources and indirectly targets low-cost firms since these are the firms that are more likely to operate during a downturn. In addition, there are gains from consolidation and targeting, though as China's experience suggests, it can be difficult for the government to pick the most efficient firms.

7 Rationales for Industrial Policy

We now assess traditional arguments in favor of industrial policy and evaluate the extent to which the policy in the shipbuilding industry is effective in achieving these objectives. Appendix E provides greater details for each of the rationales we discuss here and more.

In the presence of market power, there are in principle strategic trade benefits from subsidizing industries that compete with foreign firms (Dixit, 1984; Krugman, 1986; Eaton and Grossman, 1986; Brander, 1995). For these considerations to be relevant, a necessary condition is the existence of substantial market power and thus 'rents on the table' that, when shifted from foreign to domestic firms, outweighs the cost of subsidies. To investigate this, we carry out a counterfactual simulation where firms are price takers in the product market, which eliminates any strategic trade motives behind industrial policy (Table E20). The overall return of subsidies with perfect competition is lower than our baseline estimates, but the gap is modest (14% vs. 18%). The difference is mainly driven by production subsidies becoming less effective when firms are price takers (their return drops from 50% to 38%). These results suggest that market power considerations in the shipbuilding industry cannot justify the strategic trade arguments, consistent with results in Section 5.1 that markups are low.

Another justification for subsidies is the presence of positive externalities (such as industry-wide learning-by-doing), in which case each firm produces less than socially optimal. As discussed in Section 5.1, there is no evidence of significant spillover effects in this industry, corroborating industry reports that much of the production by Chinese shipyards occurs in product sectors with mature technologies where the scope for learning is limited.⁴¹

Industrial policies are often argued on the grounds of labor market consequences: subsidies could

⁴¹There might be technological 'catching-up' and learning among Chinese shipyards for producing the latest generation ships (e.g. large containerships or LNG's), where most of the patents and 'know-how' are possessed by Japanese and South Korean firms. Unfortunately, there are few orders of these ships, and we cannot directly test this.

have welfare benefits if they increase employment or offset distortions that lead to depressed employment. Even in the grand scheme of things, total employment in shipbuilding and related industries (ship repairs, marine equipment, etc.) accounts for less than 0.1% of national employment, suggesting that any potential labor market benefits would be modest.⁴²

There are potential spillovers to upstream sectors, as intermediate inputs from other sectors account for 50-60% of the value of ships and steel contributes to another 25-30% (Jiang and Strandenæs, 2012). One might argue that shipbuilding subsidies are partially designed to boost demand for steel, a strategic sector that is subject to many policy interventions. However, steel used in shipbuilding accounts for less than 1.5% of total steel produced (China's 2012 Input-Output Table). Looking at downstream sectors, three-quarters of the output from this industry is used for final consumption. However, more than 80% of ships are exported, which limits the fraction of subsidy benefits that is captured domestically.

As pointed out by Hausmann and Rodrik (2003), developing countries often do not know which products they are good at producing. Some entrepreneurs incur the cost of setting up production and bear the risk of discovering products that a country is good at producing. Once this knowledge is known, it can be (sometimes quickly) imitated by followers. As a result, early entrepreneurs only capture a fraction of the social value they generate. The gap between the social and private benefits of exploration justifies government intervention, such as entry subsidies to promote entrepreneurship in the first place. Our analyses presented in Appendix E.2 indicate that cost discovery is unlikely to be important in our setting. There is no evidence that spillovers across firms or common cost shocks via cost discovery existed, firms benefited from rivals' past favorable cost shocks, or marginal costs of production decreased with the number of firms producing a ship type in the past.

Another motivation might be causing foreign firms to exit; then, if future entry is costly, China's policy could lock in a longer-term increase in market share. But only a small number of Japanese and Korean firms exited; altogether they accounted for 1.6% of global production (Appendix E.3). The additional business-stealing effect as a result of Chinese shipyards taking the place of these foreign firms is small compared to our baseline estimates, where China's world market share went up from 29% to 42%.

One rationale that might justify China's shipbuilding subsidies relates to the role of ships in international trade: a larger worldwide fleet reduces transportation costs (freight rates). As China became the world's biggest exporter and a close second largest importer in our sample period, transport cost reductions can lead to substantial increases in trade volume. To evaluate this argument, we carry out a back-of-the-envelope calculation of the subsidies' impact on China's trade volume in Appendix E.4. Subsidies reduced bulk carrier freight rates by 6.1% and containership freight rates by 2% between 2006 and 2013. Using trade elasticities from the literature (Brancaccio et al., 2020; Jeon, 2018), the industrial

⁴²According to OECD (2016), it takes eight worker-years in shipbuilding and 26 worker-years in upstream sectors to produce ships valued at \$1 million in China. As 1 unit of production subsidy is associated with 1.5 units of revenue increase (Table 5), these numbers suggest that production subsidies of \$1 million create 12 jobs in the shipbuilding sector and 39 jobs in upstream sectors for one year. Thus, subsidizing shipbuilding does not appear cost-effective to create jobs given China's GDP per capita at \$2,099 in 2006 and \$7,051 in 2013.

policy raised China's annual trade volume by 4.9% (\$144 bn) between 2006 and 2013.⁴³ The increase in trade volume was large relative to the size of the subsidies (which averaged \$11.3 bn annually between 2006 and 2013); however, calculating the welfare gains associated with the increased trade volume falls beyond the scope of this paper.

Outside economic considerations, national security and production of military ships might be another relevant factor. Data on military production is scant, and our analysis is incomplete in nature (presented in Appendix E.5).⁴⁴ The military production of naval ships is concentrated in thirteen subsidiaries of China State Shipbuilding Corporation (CSSC) and China Shipbuilding Industry Corporation (CSIC), the two largest conglomerate shipyards that are also state-owned. These subsidiaries are typically dual-use, producing both commercial and military ships in the same complex (Erickson, 2017).

Figure E8 plots the annual deliveries of naval and commercial ships from 2006 to 2013 for all Chinese shipyards (Panel a) and for the thirteen dual-use shipyards that produce both military and commercial ships (Panel b), respectively. Both types of deliveries experienced a several-fold increase during this period, although military production appeared to have accelerated after the financial crisis. Like the rest of the commercial shipyards, the dual-use shipyards also exhibited significantly higher production in both ship types, providing suggestive evidence that China's supportive policy might have benefited its military production as well. Due to the small number of observations and the difficulties in verifying data coverage, we take such evidence as suggestive.

Regardless of the motivation, our analysis evaluates various policy design considerations and the relative efficacy of different instruments that can be used as guidance for future policies.

8 Conclusion

Industrial policy, which until recently was considered old-fashioned, has reemerged in many regions around the world, including the EU and the US. Despite the strong interest from policymakers and economists alike, few studies have used firm-level data to examine the relative efficacy of different designs, as well as the long-term welfare implications of industrial policies.

We conduct such an analysis of China's industrial policy in the shipbuilding industry using firm-level data and a dynamic model of firms' entry and exit, production, and investment decisions. While subsidies significantly boosted China's world market share and buttressed China's ascent into global influence, they also exacerbated industry fragmentation and led to increased capacity idleness. The policy initially exhibited a low rate of return, though returns improved over time as the government shifted away from subsidizing all firms and adopted policies that better targeted efficient firms. An important insight from our study is that adopting counter-cyclical policies, targeting efficient firms, and intervening temporarily

⁴³For comparison, Ianchovichina and Martin (2004) estimate that China's accession to WTO led to a 40% increase in its trade volume.

⁴⁴We thank Elliott Moksiki for discovering and collecting data on military ship production from the annual report IHS Jane's Fighting Ships and Erickson (2017).

instead of long-term could significantly increase the effectiveness of industrial policies from a welfare perspective. Finally, when exploring possible objectives for China's industrial policy, we find support for non-classical rationales, such as bringing down freight rates to boost Chinese trade and suggestive evidence for military considerations.

Data Availability Statement The data and code underlying this research is available on Zenodo at <https://doi.org/10.5281/zenodo.14083198>.

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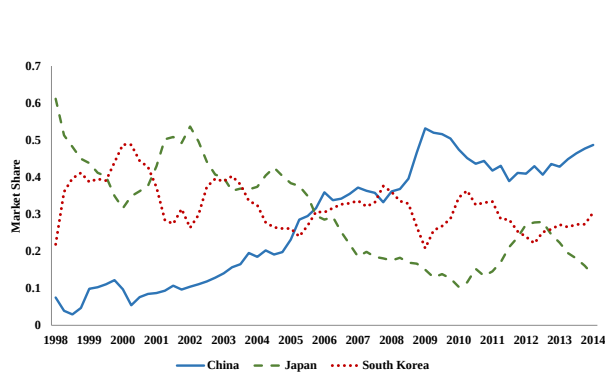
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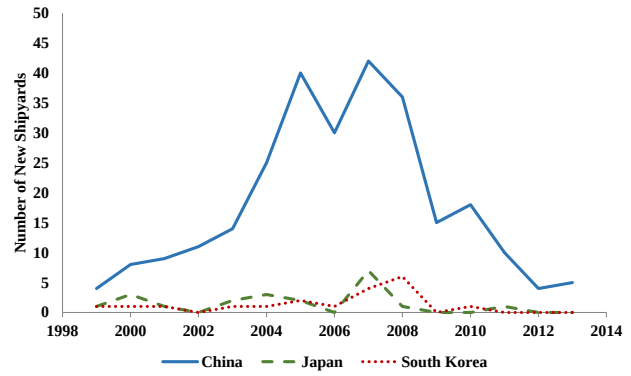
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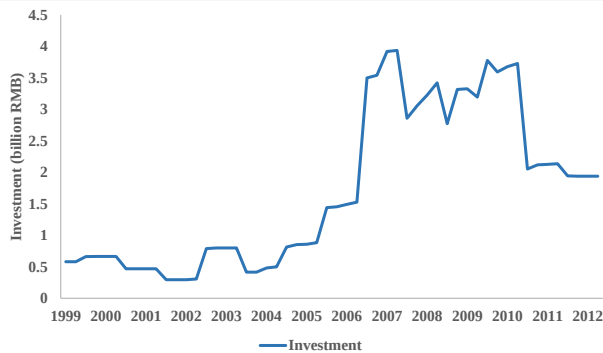
Figure 1: Evolution of the Shipbuilding Industry



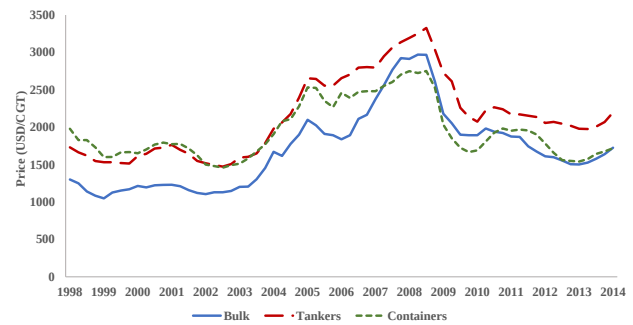
(a) China's market share expansion



(b) Entry of New Shipyards by Country



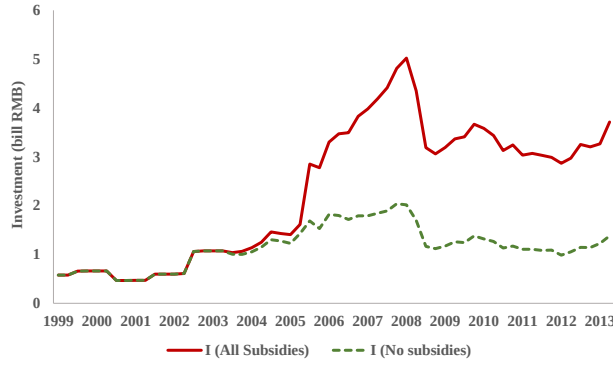
(c) Investment by Chinese Shipyards



(d) New Ship Prices

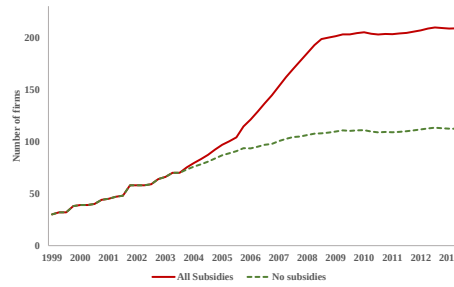
Figures (a) - (c) illustrate the rapid expansion of China's shipyard industry. a) Source: Clarkson Research. Market shares by country are computed from quarterly ship orders. b) Source: Clarkson Research. Number of new shipyards each year by country. c) Source: China's National Bureau of Statistics. Industry aggregate quarterly investment by Chinese shipyards in billions of 2000 RMB. Figure d) plots new ship prices (source: Clarksons Research). Average new ship price in nominal USD/CGT by ship type.

Figure 2: Investment, with and without Subsidies



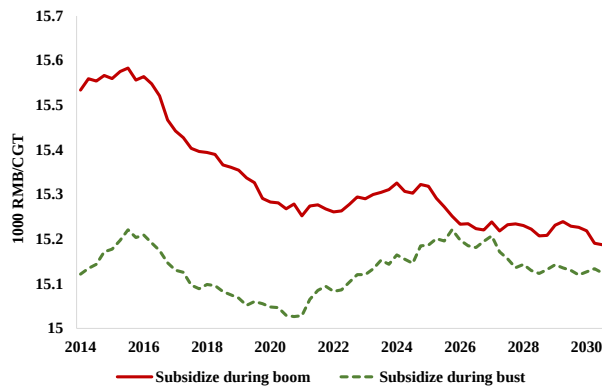
Note: Counterfactual results on total quarterly investment (in billions of 2000 RMB) with entry/production/investment subsidies (solid red line) and with no subsidies (dashed green line).

Figure 3: Number of Firms, with and without Subsidies



Note: Total number of firms in the case of all subsidies as observed in the data (solid red line) and counterfactual number of firms with no subsidies (dashed green line).

Figure 4: Marginal Cost Index with Subsidies During the Boom vs. Subsidies During the Bust



Note: The marginal cost index is defined as the portion of marginal cost determined by the firm's capital stock, backlog and other firm-level characteristics (such as age, size, and ownership status), $\bar{s}_{jt}$, and averaged across firms in thousands of 2000 RMB per CGT. The graph plots the average marginal cost index when subsidies are distributed during the boom of 2006-2008 (solid red line) vs. during the bust of 2009-2013 (dashed green line).

Table 1: Summary Statistics

Variable	Obs	Mean	S.D.	Min	Max
All Observations (including zero orders)					
Bulk carrier 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
Containership orders (1000 CGT)	4,813	18.9	93.9	0.0	1644.1
Observations With Positive Orders					
Bulk carrier 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
Containership orders (1000 CGT)	625	145.3	222.7	2.3	1,644.1
Other Variables					
Bulk carrier 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
Containership 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)	6,160	392.0	806.8	0.3	8,203.3

Note: Summary statistics for shipyards in China, Japan, and South Korea from 1998 Q1 to 2014 Q1. CGT is compensated gross tons, a widely used size measure and comparable across types. Bulk carriers, tankers, and containerships account for more than 90% of world orders in tons in our sample period. Investment and capital are limited to Chinese yards and measured in millions of 2000 RMB. Source: Clarksons and China's National Bureau of Statistics.

Table 2: Cost Function Estimates

	Bulk carrier		Tanker		Containership	
Type-specific	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
β_q	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 (Bn 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	

Note: Standard errors bootstrapped using 500 bootstrap samples. Marginal costs are measured in 1000 RMB per CGT. For example, a coefficient of -2.10 on the policy dummy ‘2006-2008’ implies that production subsidy during 2006-2008 is 2,100 RMB per CGT across ship types, or 14-18% of the average price.

Table 3: Estimates of Investment Cost and Scrap Value Parameters

	Coeff.	T-stat
σ_ϕ	0.98	12.32
$c_1 * 1\{2006-08\}$	-0.27	-1.70
$c_1 * 1\{2009+\}$	-0.46	-3.27
c_2	29.54	14.49
c_3	2.07	9.67
N	4286	

Note: Standard errors bootstrapped using 200 block bootstrap samples. Both investment and scrap value are measured in billions of 2000 constant RMB. Between 2006-2008, the subsidy was 0.27 RMB per RMB of investment. Post 2009, the subsidy jumps to 0.46 RMB per RMB of investment, which helps rationalize the elevated investment with plummeting ship prices post the financial crisis.

Table 4: Entry Cost Distribution (Mean) by Province in 2000 RMB (Bn)

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

Note: κ_{pre} : mean of the entry cost distribution prior to 2004 for Zhejiang, and prior to 2006 for Jiangsu, Liaoning and Other regions. $\kappa_{post,06}$: mean of the entry cost distribution between 2004 and 2008 for Zhejiang, between 2006 and 2008 for Jiangsu, Liaoning and Other regions. $\kappa_{post,09+}$: mean of the entry cost distribution from 2009 onwards. All entry costs are measured in billions of 2000 constant RMB. The number of potential entrants, $\bar{N}$, is assumed to equal twice the maximum number of potential entrants ever observed in a region. Compared to κ_{pre} , entry costs are much lower when entry subsidies were in place ($\kappa_{post,06}$) and much higher with entry restrictions ($\kappa_{post,09+}$). Conditional on entering, the average entry cost paid is RMB 2.5 billion, close to a shipyard's accounting value.

Table 5: Comparison of Policy Instruments

	All subsidies	Production subsidy	Investment subsidy	Entry subsidy	Remove all subsidies
Lifetime Revenue 2006-	2361	2154	1873	1961	1810
Lifetime Net Profit 2006-	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%	

Note: Revenue, net profit, and subsidy are discounted sums for Chinese shipyards from 2006 to 2050, averaged across simulations and measured in billions of 2000 constant RMB. For example, “Lifetime Revenue (Net Profit) 2006-” refers to the discounted sum of revenue (net profit) earned by Chinese firms from 2006 to 2050. “Net Profit”: Revenue-Production Cost-Investment Cost+Scrap Value-Entry Cost. “ Δ Revenue/Subsidy”: the discounted sum of revenue in the column scenario minus the discounted sum of revenue with no subsidies, divided by the discounted sum of subsidies. “ Δ Net Profit/Subsidy” equals the discounted sum of net profits in the column scenario minus the discounted sum of net profits with no subsidies, divided by the discounted sum of subsidies. Government policy in 2013 carries onward till the end of the simulation period (2050) in all columns. In Column “All subsidies”, firms receive production and investment subsidy (as estimated in the baseline) in all periods, but entry subsidy terminates in 2009. In Column “Production subsidy”, we maintain the same production subsidy as in the baseline, but shut down entry and investment subsidies. Columns “Investment subsidy” and “Entry subsidy” are similar.

Table 6: Pro-cyclical vs. Counter-cyclical Industrial Policy (in 2000 RMB, Bn)

	Subsidize during boom	Subsidize during recession
Lifetime Revenue 2006-	1880	1872
Lifetime Profits 2006-	961	975
Production Subsidy	29	29
Investment Subsidy	13	14
Δ Revenue/Subsidy	189%	168%
Δ Net Profit/Subsidy	38%	70%

Note: In Column “Subsidize during boom,” the government only subsidizes production and investment during the boom of 2006-08. In Column “Subsidize during recession,” the government subsidizes during the recession of 2009-13, but offers no subsidy before 2009 or after 2013. The subsidy rates during the 2006-08 boom are adjusted downwards to match the amount handed out during the recession. No entry subsidy is offered in either scenario. All rows are defined as in Table 5. Monetary terms are deflated and measured in billions of 2000 constant RMB.

Table 7: Alternative Designs of Industrial Policy

	Permanent Subsidy	Temporary Subsidy 2006-2013	Targeted Temporary Subsidy 2006-2013	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%	

Note: This table reports the discounted sum of revenue, net profit, and subsidy from 2014 to 2050 in billions of 2000 constant RMB, averaged across simulations. Under the permanent subsidy, all firms receive production and investment subsidies from 2006 to 2050. Under the temporary subsidy, all firms receive production and investment subsidies from 2006 to 2013, after which subsidies are discontinued. Under targeted temporary subsidy, the 50 firms with the highest profitability at the beginning of 2006 receive subsidies from 2006 to 2013, after which subsidies are discontinued. Under the no-subsidy scenario, no firms receive any subsidies. Monetary terms are deflated and measured in billions of 2000 constant RMB.