CHINA'S INDUSTRIAL POLICY:
AN EMPIRICAL EVALUATION

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ABSTRACT

Despite the historic prevalence of industrial policy and its current popularity, few empirical studies directly evaluate its welfare consequences. This paper examines an important industrial policy in China in the 2000s, aiming to propel the country's shipbuilding industry to the largest globally. Using comprehensive data on shipyards worldwide and a dynamic model of firm entry, exit, investment, and production, we find that the scale of the policy was massive and boosted China's domestic investment, entry, and world market share dramatically. On the other hand, it created sizable distortions and led to increased industry fragmentation and idleness. The effectiveness of different policy instruments is mixed: production and investment subsidies can be justified by market share considerations, but entry subsidies are wasteful. Finally, the distortions could have been significantly reduced by implementing counter-cyclical policies and by targeting subsidies towards more productive firms.

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1 Introduction

Industrial policy, broadly defined as a policy agenda aimed at shaping a country's industrial struc-ture by either promoting or restricting certain sectors, has been widely used in developed and de-veloping 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), and China, India, Brazil, and others more recently (Stiglitz and Lin, 2013). In recent years, industrial policies have reemerged and been embraced by policy makers around the world. As Ro-drik (2010) puts it, "The real question about industrial policy is not whether it should be practiced, but how."

Despite the prevalence of industrial policies in practice and the contentious debate in the lit-erature regarding their efficacy (Baldwin, 1969; Krueger, 1990), remarkably few empirical studies directly evaluate the *welfare* implications of these policies using micro-level data. Our paper fills this gap in the literature with a focus on China, the most prominent example of industrial policies currently. During the past two decades or so, Chinese firms have rapidly dominated a number of global industries, such as steel, auto, and solar panels (Figure 1), partly as a result of government support. In 2015, China unveiled its plan to 'become the leader among the world's manufacturing powers' by 2049 ("Made in China 2025").

In this paper, we focus on the shipbuilding industry, an illustrative example of the quick ascent of China's manufacturing sector into global influence during the 2000s. At the turn of the century, China's nascent shipbuilding industry accounted for less than 10% of world production. During the 11th (2006-2010) and 12th (2011-2015) National Five-Year Plans, it was dubbed a pillar industry in need of special oversight and support. Since then, an unprecedented number of national policies were issued with the goal of developing the infant industry into the largest worldwide. Within a few years, China overtook Japan and South Korea and became the leading ship producer in terms of output.

Using this historical event as a case study, we examine the welfare consequences of industry policy, focusing on three questions of general interest. First, how has China's industrial policy shaped its domestic and the global industry? Second, what are the welfare consequences of this policy? Third, what is the relative efficacy of different policy instruments, such as production subsidies (e.g., subsidized material input, export credits, and buyer financing), investment subsidies (e.g., low-interest long-term loans and expedited capital depreciation), entry subsidies (e.g., below market-rate land prices), and consolidation policies? To the best of our knowledge, this study is the first to address these questions using comprehensive micro data on the global shipbuilding industry. We build and structurally estimate a dynamic model of firm production, investment, entry, and exit, under aggregate uncertainty. The model incorporates economies of scale in firm production and

accommodates private shocks in investment decisions.

Our analysis delivers four sets of main findings. First, like many other policies unleashed by China's central government in the past few decades, the scale of the industrial policy in the shipbuilding industry is massive (relative to the size of the industry). Our estimates suggest that the policy support from 2006 to 2013 is equivalent to RMB 550 billion, with the lion's share going to entry subsidies (RMB 330 billion), followed by production subsidies (RMB 159 billion) and investment subsidies (RMB 51 billion).[1] It boosted China's domestic investment and entry by 270% and 200%, respectively, and increased its world market share by 40%, three fourths of which occurred via business stealing from rival countries. However, the policy created sizable distortions and generated merely RMB 145 billion of net profit gains to domestic producers and RMB 230 billion of worldwide consumer surplus. The policy attracted a large number of inefficient producers, exacerbated the extent of excess capacity, and did not translate into significantly higher industry profits over the long run.

Second, the effectiveness of different policy instruments is mixed. Production and investment subsidies can be justified on the grounds of revenue considerations, but entry subsidies are wasteful 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. Production subsidies are more effective at achieving output targets, while investment subsidies are less distorting over the long run. In addition, welfare losses are convex and deteriorate when multiple policies interact and induce firms to make further inefficient decisions.

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 important features of the shipbuilding industry. A counter-cyclical policy would have outperformed the pro-cyclical policy that was adopted by a large margin. Indeed, their effectiveness at raising long-run industry profit differs by nearly threefold, which is primarily driven by two factors: a composition effect (more low-cost firms operate in a bust compared to a boom) and the much cheaper expansion during recessions. In a similar vein, had the government targeted subsidies towards more efficient firms, the policy distortions would have been considerably lower.

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 chosen for government support. This strategy was adopted in several industries to curb excess capacity and create large conglomerates that can compete globally.[2] Consistent with the evidence discussed above, we find that targeting low cost firms creates less distortions; that said, the govern-

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[1]The conversion rate for this period was around 6.88 RMB for 1 US dollar.
[2]See https://www.wsj.com/articles/SB10001424127887324624404578257351843112188.

ment's White List was sub-optimal because it favored SOEs and did not include the most efficient firms. Finally, the profit gains of a policy package that involves entry subsidies (to overcome entry barriers and capital market inefficiencies) followed by a consolidation phase (to reduce fragmentation) is dwarfed by the cost of the subsidies and do not provide a compelling justification for subsidizing the industry.

A potential drawback of our analysis is that our model does not feature any market failure; as a result, industrial policy is necessarily welfare-reducing and our results essentially speak to its costs. To investigate whether this is reasonable, we explore a number of traditional rationales for industrial policy. We find limited evidence that the shipbuilding industry generates significant spillovers to the rest of the domestic economy (e.g., steel production, ship owning, and the labor market). Nor do we find evidence of industry-wide learning-by-doing (Marshallian externalities) or support for strategic trade considerations. In terms of the benefits to Chinese trade, the policy implemented in the shipbuilding industry may have lowered freight rates and boosted China's imports and exports; though evaluating the associated welfare gains falls beyond the scope of this paper. Finally, it is worth noting that non-economic arguments, such as national security, military considerations, and the desire to be world number one (Grossman, 1990), could also be important in the design of this policy. Regardless of the motivation, our analysis provides cost estimates (and welfare losses) and the relative efficacy of implementing these policies that can be used as a guidance for future polices.

Literature Review   There is a large theoretical literature on industrial policies (Hirschman, 1958; Krugman, 1991; Harrison and Rodriguez-Clare, 2010; Stiglitz et al., 2013; Liu, 2018; 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; Hansen et al., 2003; Head, 1994; Luzio and Greenstein, 1995; Irwin, 2000), while recent studies recognize the importance of measuring the impact on productivity and cross-sector spillovers (Aghion et al., 2015; Lane, 2017). A 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 (Neumark and Simpson, 2015; Criscuolo et al., 2019), and environmental subsidies (e.g., renewable energy subsidies, Yi et al. 2015; Aldy et al. 2018). To the best of our knowledge, our paper provides the first (global) welfare analysis of a large-scale industrial policy and a comparison of different policy instruments using firm-level data.

Our study is related to a small and growing literature on the shipbuilding industry. Thompson (2001) studies learning in the shipbuilding industry, using as a case study the Liberty shipbuilding program during World War II. Hanlon (2018) studies competition between British and North American shipbuilders during the late 19th and early 20th centuries and illustrates that temporary

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cost advantages can translate into a persistent competitive advantage due to the presence of learning. Kalouptsidi (2018) is closely related to our paper and detects evidence of *production* subsidies by the Chinese government in the Handysize segment within the dry bulk sector. In addition to analyzing the entire shipbuilding industry that includes all dry bulk ships, tankers, and containerships, we conduct a positive analysis of the welfare consequences of different policies used by the government. A central element in this paper is firm investment and entry/exit, which is abstracted away in the previous study that only explores firm production decisions.

Methodologically, we build on the literature on dynamic estimation, including Bajari et al. (2007); Ackerberg 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 investments chosen by observably similar firms, while at the same time accommodates inaction and various adjustment costs. Our analysis on firm investment builds on Ackerberg 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.

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 incorporates industrial policy into a market equilibrium model of ship demand and supply. Section 4 describes our strategy for estimating each component of the model. The estimation results are presented in Section 5. Section 6 quantifies the welfare impact of the industrial policy and evaluates different policy instruments. Section 7 concludes.

2   Industry Background and Data

2.1   Industry Background

Shipbuilding is a classic target of industrial policies, as it is 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 followed Japan and South Korea and supported the shipbuilding industry via a broad set of policy instruments.

The scope and frequency of national policies issued in China in the 2000s, especially after 2005

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to support its domestic shipbuilding industry is unprecedented. In 2002, when former Premier Zhu inspected the China State Shipbuilding Corporation (CSSC), one of the two largest shipbuilding conglomerates in China, he 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 Heibei), 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 shipbuilding companies 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 quotas. 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 tonnes (DWT) to be achieved by 2010, and 22 million DWT by 2015. Both goals were met several years in advance. Table 1 documents major national policies issued during our sample period.

The government adopted interventions that affected firms along several dimensions. We group policies that supported the Chinese shipbuilding industry into three categories: 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 local banks constitute other important components of production subsidies.[3] To help attract buyers, shipyards have traditionally offered loans and various financial services to facilitate purchasing payment. Investment subsidies take the form of low-interest long-term loans and other favorable credit terms that reduce the cost of investment, as well as preferential tax policies that allow for accelerated capital depreciation. Finally, shortened processing time and simplified licensing procedures, as well as heavily subsidized land prices along the coastal regions, greatly lower the cost of entry for potential shipyards.

An often explicitly-stated goal of China's industrial policy is to create large successful firms that can compete against international conglomerates. In the aftermath of the 2008 economic crisis

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[3]Until 2016, the Chinese government provided a range of subsidies for exporters, including reduced corporate income taxes, refund of the value-added-tax, etc. Shipbuilding companies benefit from export subsidies since most of their products are traded internationally.

that led to a sharp decline in global ship prices, the government promoted consolidation policies. The *Plan on Adjusting and Revitalizing the Shipbuilding Industry*, implemented in 2009, resulted in an immediate moratorium on entry with increased investment subsidies to existing firms. The most crucial policy for achieving consolidation objectives was the *Shipbuilding Industry Standard and Conditions* (2013), which instructed the government to periodically announce a list of selected firms that "meet the industry standard" and thus receive priority in subsidies and bank financing.[4] 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, tankers, and containerships, which account for more than 90% of world orders in tons in our sample period. Dry bulk ships transport homogeneous and unpacked goods, such as iron ore, grain, coal, steel, etc., for individual shippers on non-scheduled routes. Tankers carry chemicals, crude oil, and other oil products. Containerships carry containerized cargos 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 collectively account for over 90% of the world production. We limit our empirical analysis to shipyards in 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. We observe each yard's orders, deliveries, and backlog (which are undelivered orders that are under construction) measured in Compensated Gross Tonnage (CGT), for all of the major ship types, including bulk, tankers, and containers. 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 entry year for a shipyard is defined as the first year it takes an order or the first year it delivers minus two years to account for the time it takes to build a ship, whichever is earlier.[5]

The second data source is the annual database compiled by the National Bureau of Statistics

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

[5]As an additional measure of firm entry, we successfully extracted the registration information (date and business scope) for 90% of Chinese firms, from the Trade and Industry Bureau database. The registration data is an imperfect measure of entry since firms often register with a wide business scope (ship building and repairs, marine equipment, marine engineering, etc.), and it is difficult to identify firms whose core business is shipbuilding from the registration data alone. In addition, some firms switch from ship repairs and marine equipment to shipbuilding years after registering with the Trade and Industry Bureau. As such, we use the entry year from the Clarkson's database in our main analysis. Nonetheless, the overall entry pattern is similar across these two measures: entry peaked in 2005-2007 and became minimal post 2009.

(NBS) on Chinese manufacturing firms with annual sales above five million RMB. For each shipyard and year, we observe its location (province and city) and ownership status (state-owned enterprises (SOEs), privately owned, or joint ventures with foreign investors). 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. We link firms over time and construct their real capital stock and investment following the procedure described by Brandt et al. (2012). We also observe the annual accounting operation costs for each shipyard. One limitation of the NBS database is that data for 2010 are missing. This prevents us from constructing the firm-level investment in either 2009 or 2010, since investment is imputed from changes in the capital stock.

In addition to these firm-level variables, we collect a number of aggregate variables for the shipbuilding industry, including quarterly global prices per CGT for each of the three ship types.[6] The steel ship plate price serves as a proxy for changes in the production cost, 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.

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. Indeed, China became the largest shipbuilding country in terms of deadweight tons in 2009, overtaking South Korea and Japan. Figure 2 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 area. Figure 3 plots the total number of new shipyards by year for China, Japan, and South Korea. The number of entrants is modest for Japan (1.4 per year) and South Korea (1.2 per year), partly due to a lack of greenfield sites to build new shipyards. 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 subsidy was 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*.[7]

The rise in entry was accompanied by a large and unprecedented increase in capital expansion (Figure 4). 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 status. Indeed, entrants account for 43% of the aggregate investment from 2006 to 2011,

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[6]We experiment with two price indices, real RMB/CGT vs. USD/CGT, and obtain nearly identical results, suggesting that exchange rate fluctuations are not first-order in our analysis.

[7]No 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) that we see in Clarksons from 2009 onward.

with the remaining 57% implemented by incumbents. Private firms, joint ventures, and SOEs account 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.

The rapid rise in China's production, entry, and investment coincided with the introduction of China's industrial policies for the shipbuilding industry. The global shipbuilding industry went through a boom in the mid-2000s, roughly concurrent with China's initial expansion. As Figure 5 shows, ship prices began rising around 2003 and peaked in 2008, before collapsing in the aftermath of the financial crisis and remaining stagnant from 2009 through to 2013. China's production and investment, on the other hand, continued to expand well after the financial crisis.

Table 2 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 bulk and less frequently for tanker 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, combined with Chinese shipyards becoming increasingly vulnerable to long periods of inaction in the latter part of our sample, is a key feature of the shipbuilding 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 ships 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 make static production decisions to maximize their variable profit taking global ship prices as given. 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, as well as the cost of entry. 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 is a quarter. In period t, there are $j = 1, ..., J_t$ firms in the world that produce ships. There are $m = 1, ..., M$ types of ships, such as dry bulkers, tankers, and containerships. Ships within a type are homogeneous.

Ship Demand In each period, the aggregate inverse demand for ships of type m is given by the function,

$$P_{mt} = P(Q_{mt}, d_{mt}) \tag{1}$$

for $m = 1, ..., M$, where P_{mt} is the market price of ship type m in period t, Q_{mt} is the total tonnage of type m 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 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. Fixed costs are often abstracted away in empirical studies, but in later periods of our sample when the aggregate demand for new ships plummeted and many shipyards reported prolonged periods with zero production, such costs are first order. They capture wages and compensation for managers, capital maintenance, land usage, etc.

The second term, $c_m(q_{jmt}, s_{jmt}, \omega_{jmt})$, is the standard production cost. We use s_{jmt} to denote firm characteristics (e.g. capital, backlog, age, location, ownership status), as well as aggregate cost shifters that affect all shipyards (e.g. government subsidies, steel prices). In addition, production costs depend on a shock ω_{jmt}: the larger ω_{jmt} is, the less productive the firm is. The marginal cost of production is given by $MC(q_{jmt}, s_{jmt}, \omega_{jmt})$.

Firms are price takers and choose how many tons to produce for ship type m, q_{jmt}, to maximize their profits:

$$\max_{q_{jmt}} \pi(s_{jmt}, \omega_{jmt}) = P_{mt} q_{jmt} - C(q_{jmt}, s_{jmt}, \omega_{jmt})$$

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

$$P_{mt} = MC_m(q_{jmt}^*, s_{jmt}, \omega_{jmt}) \tag{2}$$

Let $s_{jt} = \{s_{j1t}, ..., s_{jMt}\}$ and $\omega_{jt} = \{\omega_{j1t}, ..., \omega_{jMt}\}$ denote the union across ship types of observed state variables and unobserved cost shocks, respectively. Note that with a slight abuse of notation, we now use s_{jmt} to denote all observed payoff relevant variables, which include ship prices in addition to cost shifters. A firm's total expected profit from all types, before the cost shocks are realized, is given by:

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

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 scrap or sell-off value, ϕ_{jt}, that is distributed 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 distributed i.i.d. with distribution F_v and chooses investment i_{jt} at cost $C^i(i_{jt}, v_{jt})$. The amount invested i_{jt} is added to the firm's capital stock next period, which in turn affects its future production costs.

The value function for incumbent firm j is:

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

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

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

where $CV(s_{jt})$ denotes the continuation value, which includes the expected cost of optimal investment and the discounted future stream of profits. Crucially, $E_{v_{jt}}$ 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: the firm 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, $p^x(s_{jt})$, defined by,

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

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:

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

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, firm j opts for no investment. Capital depreciates at a rate δ that is common to all firms.

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

$$C^i(i_{jt}, v_{jt}) = c_1 i_{jt} + c_2 i_{jt}^2 + c_3 v_{jt} i_{jt} + c_4 T_t i_{jt} \qquad (7)$$

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This (quadratic) specification borrows from the macro literature on investment costs (Cooper and Haltiwanger, 2006) with two important differences. First, investment costs depend on the unobserved marginal cost shock ν_{jt}. Much of the existing literature has focused on the lumpy nature of investment (inaction) and adjustment costs, but has shied away from modeling heterogeneous investment decisions among observationally similar firms.[8] Here, we tackle this heterogeneity by introducing ν_{jt} that shifts the marginal cost of investment across firms. Note that ν_{jt} can also explain inaction: firms with unfavorably large ν_{jt} will choose not to invest. In practice, there are many factors that influence firms' investment decisions. Some firms have political connections that grant them favorable access to the capital market (Magnolfi and Roncoroni, 2018), and others might be experienced at sourcing from equipment suppliers at low costs. In our estimation, once we control for ν_{jt}, additional adjustment costs, such as $\frac{i_{jt}^2}{k_{jt}}$ and/or a (random) fixed cost, contribute little to the model fit.[9] A second difference from the literature, is that we allow government policies T_t to directly affect the marginal cost of investment.

Entry In each period t, $\bar{N}$ potential entrants observe the payoff relevant state variables and their own entry cost κ_{jt}, which is i.i.d., and make a one-time entry decision. The entry cost is drawn from a distribution F_κ that is shifted by the government policy. If potential entrant j decides not to enter, it vanishes with a payoff of zero.[10] If j enters, it pays the entry cost and continues as an incumbent next period. In addition, the entrant is assumed to be endowed with a random initial capital stock that is realized the following period once the firm becomes an incumbent and begins operation.

Potential entrant j solves,

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

where κ_{jt} is the entry cost, k_{jt+1} is entrant j's initial capital stock in period $t+1$ after paying a cost of $C^i(k_{jt+1})$. 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 optimal threshold form: a potential

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

[9]The estimated fixed cost of investment, once included, is economically small. Fixed costs are associated with an inaction region where firms make no investment. The larger the fixed cost, the larger the inaction region. In our data, firms frequently make small investments, which is inconsistent with a large fixed cost.

[10]Here we follow the bulk of the empirical literature on industry dynamics (Ericson and Pakes, 1995), where the entry decision involves a simple comparison between the value from entering the market and the random entry cost.

entrant enters the market if the entry cost κ_{jt} drawn is lower than the value of entering, i.e.

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

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

$$p_t^e \equiv \Pr\left(\kappa_{jt} \leq VE_{jt}\right) = F_\kappa\left(VE(s_{jt})\right) \tag{8}$$

Industrial Policy Industrial policies affect the costs of production, investment, and entry and are thus part of the payoff relevant state variables, s_{jt}. We assume that these policies are unexpected and perceived as permanent by all shipyards once they are in place. This is consistent with the empirical patterns documented in Section 2.3, where the spike in entry and investment coincides remarkably with the timing of these policies.

Equilibrium The Markov Perfect Equilibrium (MPE) of this model is defined as follows:

Definition 1. An equilibrium of this model consists of policies, $\{q_{jmt}\}_{m=1}^M$, $i^*(s_{jt}, v_{jt})$, $p^x(s_{jt})$, p_t^e, value function $V(s_{jt})$ and prices P_{mt}, such that the production quantity satisfies (2) and maximizes the period profit, the investment policy satisfies (6), the exit policy satisfies (5), the entry policy satisfies (8), and ship prices clear the market each period so that aggregate demand equals total supply. Moreover, the incumbent's value function satisfies (3) and firms employ the above policies to form expectations.

The key assumption in invoking the MPE concept is that the transition processes of all payoff relevant state variables (including ship prices) satisfy the Markovian property pre and post the policy intervention. Consequently, the equilibrium is stationary conditioning on our state variables (which include dummy variables for different policies) and the value functions are not indexed by t. While China's market share increased substantially during our sample period, such an expansion can be explained by changes in state variables, including demand and cost factors, as well as policy interventions.[11]

Discussion We close this section with a brief discussion on our assumptions. We assume that shipyards are price-takers. This assumption is motivated by the large number of firms in the industry. As discussed above, there are more than four hundred shipyards globally and the market share of the largest firm is less than 5%. The market is thus sufficiently unconcentrated that market

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[11]Stationarity does not preclude business cycles, which are typical in the world shipbuilding industry. We use ship prices to capture the aggregate business cycles. Relaxing the stationarity assumption is a difficult but important topic for future research.

power is not a first order consideration. Nonetheless, we consider a variation of our model that incorporates market power with firms being Cournot competitors in the product market. In that case, the optimal production of firm j in period t (when positive) satisfies a variant of the first order condition (2) that includes a markup equal to $-q_{jmt}\left[\partial P(Q_{mt}, d_{mt})/\partial q_{jmt}\right]$. Empirically, this term turns out to be small and the estimates are robust when replicated under the Cournot assumption. It is also worth noting that on the ship buyer side (shipowners), monopsony power is not a first-order issue as the concentration among ship ownership is also low.[12]

Ships are assumed homogeneous within a type conditioning on size. In prior work (Kalouptsidi (2014), Brancaccio et al. (2018)), this assumption is substantiated for dry bulkers. These papers show that both in secondary markets for ships, as well as in transport contracts, the majority of price variation is accounted for by a ship's age and aggregate indicators of economic activity. To further substantiate this assumption, we explore a small sample of new ship purchase contracts with detailed price information and ship attributes. Ship type, ship size (measured in Compensated Gross Tonnage), and quarter dummies explain most of the price variation: the R^2 of a hedonic price regression when these are the only regressors is 0.93 for bulk, 0.94 for tankers, and 0.75 for containers. Ship and shipyard characteristics (age, country, number of docks and berths, etc.) have limited explanatory power: adding shipyard fixed effects to the hedonic regressions adds little to the fit with the exception of containers where the R^2 does increase.

We assume away dynamic considerations in production. In practice, producing a ship takes time and the production decision is in general dynamic: production today affects the backlog tomorrow, which affects tomorrow's operation costs and therefore production decisions. However, as documented in Kalouptsidi (2018), cost function estimates under static and dynamic assumptions are fairly similar, especially the estimates that reflect the impact of policy interventions on firms' production costs. This is partly because the amount of drastic production expansion seen in practice cannot be entirely explained by the inter-temporal considerations that arise with a dynamic production. Note that we allow backlogs to directly affect the marginal cost of production, which proxies for the dynamic considerations in production decisions in a reduced-form manner.

Moreover, we model shipyards' production decision in tonnage, rather than number of ships. Modeling the optimization decisions in both the number and size (tonnage) of ships is substantially more complicated. Since our main focus here is on entry, exit, and investment, we thus make the simplifying assumption that shipyards choose production in tonnage to maximize their static profits. This keeps the model tractable. It is worth noting that our estimated production subsidies are consistent with those in Kalouptsidi (2018) that models the choice of the number of ships and focuses on shipyards producing a specific size category of dry bulkers, Handysize vessels.

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[12]The containership segment may be concentrated among the operators, but they lease containerships from many shipowning firms.

We assume that the cost shocks ω_{jmt} are i.i.d. There are several reasons for this choice. First, ω_{jmt} is estimated to be only moderately persistent, with a serial autocorrelation of 0.28 for bulk, 0.27 for tankers, and 0.39 for containerships. It is worth noting that our estimation procedure on production cost parameters accommodates persistence in ω_{jmt} (see Section 4.1). Second, while it is straightforward to estimate the persistence of these shocks using observed quantity choices, incorporating a persistent time-varying unobserved state variable in a dynamic model raises considerable modeling and estimation challenges. For the same reason, the investment cost shocks ν_{jt} are assumed i.i.d. Given that aggregate investment increased by more than four-fold within a year upon the announcement of the 11th National Five-Year Plan (Figure 4) and that all firms expanded regardless of their efficiency level, firm-specific persistent investment shocks are unlikely a first-order contributing factor to the boom of the capital expansion observed in our sample.

Lastly, the government policies are perceived as permanent by all firms. This is likely a strong assumption, since China's economy is experiencing a drastic transformation with a highly dynamic policy environment. This assumption, however, is standard in the literature (Ryan, 2012). Relaxing it 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). One (imperfect) approach to proxy for a dynamic policy environment is to use lower discount rates so that future profits are less relevant for today's decisions. We indeed test for the robustness of our results with different discount rates.

4 Estimation Strategy

In this section, we present the empirical approach undertaken to uncover the model parameters. 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 the dynamic decisions (entry, exit, and investment) for Chinese shipyards as there is little entry, exit, and capacity expansion in Japan and South Korea (OECD, 2015, 2016).

We first estimate the demand curve for new ships, as well as the shipyard production costs. We refer to these parameters as the "static parameters". We use these estimates to construct firm profits in each period. Next, we estimate the parameters governing investment costs and the scrap values for exiting firms, i.e. the "dynamic parameters". This constitutes the bulk of our dynamic estimation where we adopt a two-step procedure in the tradition of Hotz and Miller (1993) and Bajari et al. (2007). Finally, we estimate entry costs.[13] We next describe our approach in detail.

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[13]Combining step two and three and estimating all dynamic parameters jointly is more efficient but computationally more challenging.

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 the dynamic parameters (investment cost, scrap values, as well as entry costs).

4.1 Estimation of Static Parameters

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

$$Q_{mt} = \alpha_{0m} + \alpha_{pm}P_{mt} + d'_{mt}\alpha_{dm} + \varepsilon^d_{mt} \tag{9}$$

The demand shifters d_{mt} include freight rates, the total backlog of type m, and some other type-specific variables. Demand for new ships is higher when demand for shipping services is high, reflected in higher freight rates.[14] 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 for each ship type we consider: the wheat price and Chinese iron ore imports for bulk carriers; Middle Eastern refinery production for oil tankers; and world car trade for containerships. In some specifications, we allow for time trends as well. 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.[15] Steel is a major input in shipbuilding and contributes to 13% of the costs (Stopford, 2009). The identification assumption is that steel prices and steel production are uncorrelated with new ship demand shocks ε^d_{mt}. This is a plausible assumption because only a modest portion of global steel production is used in shipbuilding and an increase in ship demand ($\varepsilon^d_{mt} > 0$) is unlikely to have much impact on steel prices.[16]

As there is a single global market for each ship type, the demand curves are estimated from time series variation. To improve the precision of parameter estimates, we restrict some parameters to be the same across ship types and estimate equation (9) jointly across the three types using GMM.

Production Cost We parameterize the marginal cost function for type m, $MC_m\left(q_{jmt}, s_{jmt}, \omega_{jmt}\right)$, as follows:

$$MC_m(q_{jmt}, s_{jmt}, \omega_{jmt}) = \beta_{0m} + s_{jmt}\beta_{sm} + \beta_{qm}q_{jmt} + \omega_{jmt} \tag{10}$$

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[14]The 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.

[15]Other potential instruments include the aggregate number of shipyards, J_t, and the aggregate capital stock. These cost-side instruments shift the industry supply curve and are determined in period $t - 1$, before demand shocks in period t are realized. Results are robust with or without these additional IVs.

[16]In addition, internationally traded steel accounts for less than 8% of the volume of goods transported by dry bulkers (UNCTAD, 2018). Thus, changes in the steel price that affect the amount of steel transported by sea are unlikely to directly affect demand for dry bulkers.

where q_{jmt} denotes tons of ship type m chosen by firm j in period t. It is worth noting that because of time to build, there is a difference between the orders placed in a period, the deliveries, and the production. We use orders as a measure of q_{jmt}, following Kalouptsidi (2018). We do so because the number of tons ordered is the relevant quantity decision made by the firm. In addition, our data source reports orders and deliveries instead of production and it is not straightforward to infer production from orders. Last but not least, the decision on orders corresponds to observed prices, while any constructed measure of production does not.

State variables s_{jmt} include firm j's capital and backlog of all ship types. The capital stock, which is controlled by the firm through the investment decisions over time, reduces production costs by allowing the firm to achieve economies of scale. The backlogs also capture economies of scale, as well as learning by doing, and possibly capacity constraints. The vector s_{jmt} in addition contains the 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.[17] Finally, 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 optimal production q_{jmt}^*, if positive, satisfies the first order condition that equates the marginal cost of production to the price:

$$q_{jmt}^* = \frac{1}{\beta_{qm}}\left(P_{mt} - \beta_{0m} - s_{jmt}\beta_{sm} - \omega_{jmt}\right)$$

The yard chooses positive production if and only if:

$$\omega_{jmt} < P_{mt} - \beta_{0m} - s_{jmt}\beta_{sm}$$

Besides observed shipyard attributes, zero production is driven by unfavorable cost shocks: firms with high cost shocks are more likely to stay idle.

The parameters characterizing shipyards' production costs are $\theta^q \equiv \left\{\beta_{0m}, \beta_{sm}, \beta_{qm}, \sigma_{\omega m}\right\}_{m=1}^M$ and are estimated via MLE. The sample likelihood of the Tobit model is:

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

It is worth noting that θ^q is consistently estimated even when ω_{jmt} is correlated over time, despite

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[17]Large firms are defined as the top firms that account for 90% of the aggregate industry revenue from ship production throughout our sample period. There are fifty-five large Chinese shipyards. Adding this variable (on top of capital and other firm attributes) helps to capture unobserved differences across firms, like management skills, political connections, etc. and improves the fit of our model.

the fact that this likelihood function assumes (erroneously) that ω_{jmt} is i.i.d. (Robinson, 1982).[18] To obtain the standard errors allowing for autocorrelation in ω_{jmt}, we use 500 block bootstraps.

Finally, it should be noted that a firm's production decisions provide no information on its fixed cost c_0, since the firm incurs this cost regardless of whether it produces. However, unlike most empirical studies where fixed costs are assumed away, we take advantage of accounting cost data to calibrate c_0, exploiting the fact that firms report costs incurred even during periods when the production facility is idle. Details on this calibration procedure are reported in Appendix A.1. Restricting the fixed cost to zero may bias the counterfactual analyses (Aguirregabiria and Suzuki, 2014; Kalouptsidi et al., 2018); we discuss this issue further in Section 6.1.

4.2 Estimation of Dynamic Parameters

We now turn to the estimation of the dynamic parameters, i.e. the investment cost, the scrap value distribution, and the entry cost distribution. To estimate these parameters, we rely on firm choices regarding investment, entry and exit. An important complication in doing so is that optimal choices depend on the value function (as well as an unobserved shock in the case of 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. Here we approximate the value function by a set of B-spline basis functions of the state variables, following Sweeting (2013) and Barwick and Pathak (2015). In the second stage, once we have an estimate of the value function, we formulate the likelihood of the observed investment and exit and recover the dynamic parameters of interest. We next describe each step. Appendix A contains additional details.

4.2.1 First Stage

Exit Policy Function Estimating the exit policy function can be done via a number of different approaches (linear probability models, logit or probit, local polynomial regressions, etc.). Here, we perform a probit regression, though results appear robust across different 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 $\hat{p}^x(s_{jt})$.

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[18]Intuitively 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.

Investment Policy Function Recall that the cost of investment, $C^i(i_{jt}, v_{jt})$, has the following form:

$$C^i(i_{jt}, v_{jt}) = c_1 i_{jt} + c_2 i_{jt}^2 + c_3 v_{jt} i_{jt} + c_4 T_t i_{jt}$$

The random investment cost shock v_{jt} helps to rationalize different investment decisions by observably similar firms. To our knowledge, this is one of the first empirical analyses that incorporates this feature in the context of continuous investment.

The optimal investment policy function $i_{jt}^*(s_{jt}, v_{jt})$ is implicitly defined by the following first order condition:

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

with equality if and only if i^* is strictly positive. 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.[19] As a result, conditioning on s_{jt}, the jth quantile of v_{jt} corresponds to the $(100 - j^{th})$ quantile of i_{jt} in the data. As shown in Bajari et al. (2007) and Ackerberg et al. (2007), we can recover the optimal investment policy function $i_{jt}^*(s_{jt}, v_{jt})$ as follows:

$$F(i|s_{jt}) = Pr(i_{jt}^* \leq i|s_{jt}) = Pr(v_{jt} \geq i^{*-1}(s_{jt}, i)|s_{jt}) = Pr(v_{jt} \geq v|s_{jt})$$
$$= 1 - F_v(v|s_{jt})$$

which implies $\quad i^*|s_{jt} = F^{-1}\left(1 - F_v(v|s_{jt})\right)$ $\qquad\qquad$ (11)

where $F(i|s_{jt})$ denotes the empirical distribution of investment given the state variables and F_v is the distribution of v. The data requirement for estimating this conditional distribution non-parametrically increases dramatically with the number of state variables and becomes challenging in our setting. Therefore, we make the simplifying assumption that the optimal investment function is additive in v_{jt}:

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

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 separately identified from $h_2(v_{jt})$ non-parametrically, we assume that v_{jt} is distributed standard normal. We first flexibly regress observed investment on the state variables to obtain an estimate of $h_1(s_{jt})$. Then we employ equation (11) to obtain an estimate of $h_2(v_{jt})$, treating $i_{jt}^* - \hat{h}_1(s_{jt})$ as the relevant data.

We do not incorporate divestment in our analysis. Compared to the massive investment under-

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

taken by Chinese shipyards, divestment is much less common and an order of magnitude smaller.[20] Modeling the level of divestment with irreversible adjustment costs (firms only recoup a fraction of the nominal value of their capital goods when they sell them) introduces a kink in the cost function and makes the value function non-differentiable, which raises considerable computational challenges. As a result, we abstract away from formulating the magnitude of divestment.

To address the issue that investment is non-negative, in addition to estimating the investment policy function as above, we perform two robustness checks. The first is a Tobit model that assumes $h_2(v_{jt})$ is normally distributed. The second approach assumes that the median of $h_2(v_{jt})$ is zero and estimates $h_1(s_{jt})$ using the Censored Least Absolute Deviation estimator (CLAD) that was first proposed by Powell (1984) and later extended by Chernozhukov and Hong (2002). With an estimated $h_1(s_{jt})$ at hand, we non-parametrically estimate $h_2(v_{jt})$ using a modified version of (11) that takes advantage of the assumption that i_{jt}^* is additively separable in s_{jt} and v_{jt}. Appendix A provides more details.

State Transition Process Some of the state variables included in s_{jt}, such as the province and ownership status, are fixed over time. The transition process for age is deterministic. Capital (k_{jt}) depreciates at a common rate δ, so that

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

We calibrate δ to 2.3% quarterly (Brandt et al., 2012), reflecting China's high interest rates over our sample period. Similar to capital, the firm's backlog in period $t + 1$ is determined by orders and deliveries in period t. We assume backlog at time $t + 1$ satisfies an AR(1) process: $b_{jmt+1} = (1 - \delta_{bm})b_{jmt} + q_{jmt}$, and calibrate δ_{bm} based on average deliveries.[21]

Finally, we need to specify firm beliefs over the transition process of steel and ship prices. 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 intersection of aggregate demand and supply. Following other work in the literature (e.g. Aguirregabiria and Nevo 2013), we model shipyards' beliefs about ship prices as an AR(1) process. This is a behavioral assumption: firms do not follow the production decisions of hundreds of rivals to predict future ship prices. They instead use the AR(1) process as a heuristic rule. The introduction of the Chinese government policies presents a permanent and unanticipated shock to the industry, which can potentially change the evolution of firm beliefs over prices. To capture this, we allow the AR(1) process to differ before and after 2006 when the policies came into effect.

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[20]The aggregate divestment is about 12% of the aggregate positive investment in the industry. We also drop 5% outliers with investment exceeding RMB 250 million or capital stocks exceeding RMB 4 billion.

[21]The quarterly depreciation rate for backlog, δ_{bm}, equals 6.8% for bulk, 6.3% for tankers, and 6.2% for containers.

Value Function Approximation   Armed with estimates of the policy functions and state transitions, we now turn to the value function. We assume that the scrap value ϕ_{jt} is distributed exponentially with parameter $1/\sigma_\phi$ and obtain the ex ante value function (i.e. prior to the realization of ϕ_{jt}) as follows:

$$V(s_{jt}) \equiv E_\phi V\left(s_{jt}, \phi_{jt}\right) = E_\phi\left[\pi(s_{jt}) + \max\left\{\phi_{jt}, CV(s_{jt})\right\}\right] \tag{12}$$

$$= \pi(s_{jt}) + p^x(s_{jt})E\left(\phi_{jt}|\phi_{jt} > CV\left(s_{jt}\right)\right) + \left(1 - p^x(s_{jt})\right)CV(s_{jt}) \tag{13}$$

$$= \pi(s_{jt}) + p^x(s_{jt})\sigma_\phi + CV(s_{jt})$$

where we use the fact that $E(\phi|\phi > CV) = \sigma_\phi + CV$, shown in 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).

The ex-ante value function in our context is smooth and can be approximated arbitrarily well by a set of B-spline basis functions of the state variables:

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

where $\{u_l(s_{jt})\}_{l=1}^{L}$ are basis functions and $\{\gamma_l\}_{l=1}^{L}$ are coefficients to be estimated. This approach has several advantages. First, it avoids discretization and approximation errors therein when the state space is large. Second, replacing an unknown function with a finite set of unknown parameters substantially reduces the computational burden. Third, the accuracy of the value function approximation can be controlled via appropriate choices of the basis functions and is directly benchmarked by the violation of the Bellman equation.[22]

We search for $\{\gamma_l\}_{l=1}^{L}$ that minimize the violation of the Bellman equation (12) given the dynamic parameters:

$$\{\gamma_l\}_{l=1}^{L} = \arg\min_{\gamma_l} \left\|V(s_{jt};\gamma) - \pi(s_{jt}) - \hat{p}^x(s_{jt})\sigma_\phi - CV(s_{jt};\gamma)\right\|_2 \tag{14}$$

where $\hat{p}^x(s_{jt})$ and $\hat{i}^*(s_{jt}, v_{jt})$ are the estimated first-stage exit and investment policy functions, respectively, $CV(s_{jt};\gamma) = E_{v_{jt}}\left\{-C^i(\hat{i}^*(s_{jt}, v_{jt})) + \beta E[V(s_{jt+1};\gamma)|s_{jt}, \hat{i}_{jt}^*]\right\}$ is the continuation value evaluated at these estimated policy functions, and $\|.\|_2$ is the L^2 norm. Equation (14) is imposed as a constraint in the estimation of the dynamic parameters, as discussed below.

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[22]Another popular approach to calculate the value function is via forward simulation. The computational burden of our approach is comparable to forward simulation when the policy function is linear in parameters.

Constructing Basis Functions   Note that several state variables enter the shipyard's payoff as a single index $s_{jmt}\beta_{sm}$ in the marginal cost of production (10), including the shipyard's region, ownership, size, age, and backlog. Instead of keeping track of each state individually, we collapse them into a single-dimensional state using the estimated coefficients:

$$\bar{s}_{jt} = -\sum_m s_{jmt}\beta_{sm} \qquad (15)$$

We use $\bar{s}_{jt}$ as a measure of a firm's observed cost efficiency: a higher $\bar{s}_{jt}$ is associated with a lower marginal cost and a higher variable profit. Our approach of collapsing firm-level state variables into a single index is similar in spirit to Hendel and Nevo (2006) and Nevo and Rossi (2008) that use the "inclusive value" to capture the impact of changing product attributes on future profits. We further assume that $\bar{s}_{jt}$ evolves via a simple rule $\bar{s}_{jt+1} = \alpha_0 + \alpha_1\bar{s}_{jt}$, which almost perfectly forecasts $\bar{s}_{jt+1}$ in period t since all but one of the variables in $\bar{s}_{jt}$ are deterministic.

Therefore, the state variables in the dynamic estimation are the capital stock, the price for each ship type, the steel price, $\bar{s}_{jt}$ (which subsumes the remaining firm characteristics), and two policy dummies for the periods 2006-08 and post 2009, respectively. The basis functions are flexible third order B-splines (i.e. quadratic piecewise polynomials). Given our focus on investment, we use two knots (and have experimented with more knots) in forming the B-splines for capital. The total number of basis functions is 44.

4.2.2   Second Stage

Investment and Exit   We estimate the dynamic parameters $\theta^i \equiv \left\{\sigma_\phi, c_1, c_2, c_3, c_4\right\}$ via MLE. Our sample likelihood includes both the likelihood for exit decisions and the likelihood for investment decisions. The scrap value is assumed to follow the exponential distribution $\phi_{jt} \sim F_\phi(\sigma_\phi)$, where σ_ϕ is the average. The investment cost shock is assumed to follow the standard normal. 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 and $f(\chi_{jt})$ is the associated likelihood.

Optimal investment, $i_{jt}^* = i^*(s_{jt}, \nu_{jt})$, if positive, is defined by the first order condition:

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

By construction, when $i^*(s_{jt}, \nu_{jt})$ is positive, it is strictly monotonic in ν_{jt}. Assuming it is also

differentiable, the likelihood of investment can be written as follows:[23]

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

where in the first row, $f_v(v_{jt})$ is the density of the 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 values ϕ_{jt} and investment shocks v_{jt} are assumed independent, the joint log-likelihood for exit and investment decisions is the sum of the two respective log-likelihoods. We maximize the sample log likelihood subject to the Bellman constraint (14):

$$\max_{\theta^i} L = \sum_{j,t} log(f(\chi_{jt};\theta^i)) + \sum_{j,t} log(g(i_{jt};\theta^i))$$

$$\text{s.t.} \quad V(s_{jt};\theta^i) = \pi(s_{jt}) + p^x(s_{jt})\sigma_\phi + CV(s_{jt};\theta^i)$$

Entry Cost Parameters   Estimating the distribution of entry costs is straightforward once the investment cost and scrap value parameters are known. A potential entrant enters if their value of entry exceeds the random draw of the entry cost:

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

We first construct the value of entry VE_{jt} using the dynamic parameter estimates and then estimate the mean entry costs using the observed entry decisions, via MLE.

One issue with the entry cost estimation is how to treat firms' initial capital stock. As the initial capital is an order of magnitude larger than observed post entry investment, our investment model cannot rationalize it as an ordinary investment decision.[24]   Therefore, we assume that the cost of the initial capital equals $C(k_{t+1}) = c_1 k_{t+1} + c_4 T_t k_{t+1}$, where k_{t+1} is drawn from the observed distribution of initial capital stocks. Essentially, we assume that firms face no adjustment costs when choosing their initial capital so that $c_2 k_{t+1}^2$ and $c_3 v_{t+1} k_{t+1}$ do not apply.

5   Results

This section follows closely the sequence in Section 4. Section 5.1 presents estimates of the static parameters (demand and production costs). Section 5.2 discusses estimates of the policy functions

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

[24]The mean capital stock upon entry is RMB 125 million, compared to the average investment of RMB 18.5 million.

and state transition process. Section 5.3 reports the dynamic parameter estimates (investment cost, scrap values, as well as entry costs).

5.1 Static Demand and Production Cost Estimates

Demand Table 3 reports estimates of the demand curve (9). Column (1) presents the simplest specification where the only demand shifter is the type-specific freight rate. Column (2) adds type-specific demand shifters. Column (3) further controls for a time trend, while Column (4) allows the time trend to differ before and after 2006. In all specifications, we allow for a different price coefficient before and after 2006, to capture changes in the slope of the demand curve after the introduction of Chinese subsidies. Given the limited number of observations for each type-specific aggregate demand, we restrict the price coefficient post 2006 and the coefficient on backlog to be the same across types. We instrument prices using the steel price and steel production and we estimate the demand system using GMM. Adding demand shifters improves the fit, though time trends appear to matter little.[25] As such we use Column (2) as our preferred specification.

Demand becomes less elastic post 2006. According to our preferred specification (Column 2), the price elasticity prior to 2006 was 1.8 for bulk and tanker, and 3.4 for containers. It fell to 0.3 for bulk, 0.6 for tanker, and 1.7 for containers post 2006.[26] As expected, 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. The remaining shifters have the expected sign.

Production Cost Table 4 shows the estimated marginal cost parameters for Chinese yards for each ship type (standard errors are computed from 500 block bootstrap samples). We allow the key parameters that characterize the curvature of the production cost to be type specific (the coefficients on quantity, capital, backlog, and steel price), but restrict the coefficients on subsidy dummies and shipyard attributes to be the same across ship types, due to the large number of parameters. There are intuitive reasons for these restrictions. For example, the effect 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, it is not unreasonable to assume that subsidies are not earmarked for a particular ship type, as firms can produce different kinds of ships depending on the prevailing market conditions.

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[25]In addition, the time trends pose a challenge to the stationarity assumption of our dynamic setup and are difficult to deal with when extrapolating beyond our sample period in the counterfactual analyses.

[26]Demand elasticity for new ships, which are durable goods, is driven by complicated dynamic considerations that include the composition of the existing fleet, the expected number of new ships to be delivered in the near future, as well as the beliefs about future freight rates and fuel costs. Hence, we have no prior as to whether it should increase or decrease post 2006.

As the Chinese policies came into effect in 2006 and underwent major changes in 2009, we include separate dummies for Chinese yards in 2006-2008 and from 2009 onwards. The production subsidy between 2006-2008 is estimated to be 1,510 RMB/CGT, which is 10-13% of the average price. The subsidy from 2009 onwards is slightly smaller, at 1,380 RMB/CGT.[27] Though our estimation method, sample period, and industry coverage are different from those in Kaloupt-sidi (2018), the estimated production subsidy is of a similar magnitude (with ours being slightly smaller), which is reassuring.

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 changes in prices. On average, a 10% price increase causes bulk production to increase by 21%, tanker production by 28%, and container production by 22%. 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 the annual marginal cost of production by 2.1% for bulk, 1.8% for tanker, and 1.7% for container. To put these numbers into context, the average firm's per-period profits would decline by 19% if its capital stock were halved.

Moreover, we find strong evidence of economies of scale in production with respect to the backlog: it is cheaper to produce multiple ships at the same time. The effect of the backlog on marginal cost is sizable: increasing the backlog by 100,000 CGT reduces the marginal cost of production by 11% to 27% on average across ship types. As backlogs continue to increase, capacity constraints become binding and drive up marginal costs, as reflected in the positive coefficient (though much smaller in magnitude) on backlog squared.

Firms located in Jiangsu, Liaoning, and Zhejiang provinces (the major shipbuilding regions in China) have lower marginal costs, by 18-22% for Jiangsu, 13-16% for Liaoning, and 10-12% for Zhejiang. The (additional) effect of ownership is limited. While private firms have the highest marginal costs, followed by small SOEs, CSSC/CSIC owned SOEs, and finally foreign JVs, none of these coefficients is statistically significant. As shipyards age, their marginal cost increases by about 1% each year. Finally, increases in the steel price raise the marginal cost for all types, as expected.

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

Our baseline specification (Table 4) estimates costs separately for each country, partly because

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[27]In robustness checks, we estimate the 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.

we only observe the capital stock for Chinese shipyards. Table 5 displays parameter estimates when shipyards from all three countries are pooled together. We set the capital variable to zero for Japanese and South Korean yards and use country dummies to control for these capital costs. The key coefficients are qualitatively similar, though the subsidy for Chinese yards during 2006-08 is estimated to be somewhat larger relative to the baseline specification. We prefer the baseline specification, which allows more flexibility in capturing production differences across countries and delivers a more conservative estimate of the subsidies.[28]

In Appendix Section A.2, we examine both within-firm and industry-wide learning-by-doing among Chinese shipyards by allowing the marginal cost of production to depend on a firm's past production as well as the industry cumulative past production. Despite the potential upward-bias of over-estimating the spillover effects in the absence of suitable instruments, our estimates suggest that there is no evidence 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 ships, especially bulk and tankers, has been around for a while and is mature. We hence take the baseline estimates from Table 4 to the dynamic estimation and counterfactual analyses.

5.2 Dynamic Parameters: First Stage

Investment policy function   Table A2 in Appendix A reports the estimates for the investment policy function using OLS, Tobit with $h_2(v)$ normally distributed, and CLAD, which does not impose a distributional assumption on v. Our preferred specification is the OLS regression, which delivers the highest model fit. Investment increases in ship prices and decreases in the steel price. Firms with higher $\bar{s}_{jt}$ (i.e., more productive) invest more all else equal. As expected, the coefficients for both the 2006-08 and 2009+ policy dummies are positive. Moreover, investment is hump-shaped with respect to capital: it initially increases in the capital stock, reaches a peak when capital equals RMB 1-1.5 billion, and then falls. Lastly, we invert the decreasing function $h_2(v)$, to obtain v in order to calculate the expected investment cost that enters the sample likelihood below.

Exit policy function   We estimate the exit policy function via a probit regression. Table A3 in Appendix A 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.

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[28]However, using the cost estimates that pool data from all three countries leads to qualitatively similar welfare results.

5.3 Dynamic Parameters: Second Stage

Investment and exit   Table 6 reports the investment cost estimates; note that following the literature on investment (Cooper and Haltiwanger, 2006), we assume that the unit investment cost is equal to one ($c_1 = 1$).[29] Between 2006-2008, the subsidy was 0.25 RMB per RMB of investment, implying that 25% of the per-unit cost of investment (excluding adjustment costs) is subsidized. Post 2009, the subsidy nearly doubles and jumps to 0.49 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. In addition, an estimated large value of c_3 implies that the shock v_{jt} plays an important role in explaining investment. Finally, the mean of the scrap value distribution is estimated to equal RMB 0.69 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.

Figure 6 plots the distribution of the observed and the simulated investment. These two distributions are reasonably similar, though the actual distribution has a heavy-tail of large investments and fewer medium-sized investments. Table 7 compares the actual number of exits with the model's estimates. Our model predicts fewer exits post 2006, with a total of 39 exits compared to a total of 48 exits observed in the sample.

Entry cost estimates   Table 8 reports the estimates for κ_{jt}, the mean entry costs, across periods while Table 9 illustrates that the simulated number of entrants is reasonably close to the actual number of entrants in each policy period. Given the different number of entrants across provinces (Zhejiang has the highest number of entrants at 95), we estimate the entry cost separately for Liaoning, Jiangsu, Zhejiang, which collectively account for 70% of new shipyards, and the rest of China.[30] The entry cost estimates range from RMB 25 billion to 91 billion prior to 2006. Conditional on entering, the average entry cost paid is RMB 2.3 billion; this is close to a shipyard's accounting value.[31] Given the unprecedented entry boom from 2006 to 2008, it is not surprising

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[29]Monte Carlo evidence indicates that it is difficult to identify all the cost parameters in equation (7).

[30]We assume that the ship type produced by an entrant is a random draw from the observed distribution of product lines for entrants in that province and is realized post-entry. In addition, entry subsidies are assumed to begin in 2004 for Zhejiang, when it identified shipbuilding as a pillar industry, and in 2006 for all other provinces. This is consistent with the empirical pattern that entry peaked earlier in Zhejiang than the rest of the country.

[31]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.

that we find substantial entry subsidies, with the fraction of entry costs that is subsidized varying from 49% in Liaoning to 64% in Jiangsu. Entry costs increased substantially in 2009 when the entry moratorium was put in place.[32]

A common challenge in estimating entry costs is setting the number of potential entrants, as this is rarely observed. Following the literature (Seim, 2006), we assume that the number of potential entrants in a region in any quarter is larger than the maximum number of entrants ever observed in that region, specifically, twice the maximum number of observed entrants. At this level, the entry rate is only 6.8% and thus leads to high estimated entry costs. We have estimated the entry cost distribution under alternative assumptions (e.g. the maximum number of entrants ever observed, or a large number such as 20 and 40). The higher the number of potential entrants, the higher the estimated κ_{jt}. While the estimates for κ_{jt} vary, the estimated entry cost paid upon entering, as well as the entry subsidies are remarkably robust, as they are essentially determined by the actual number of entrants observed in the sample.

Note that the entry costs we estimate include both the economic costs of entry (e.g. opportunity cost of land), as well as non-pecuniary costs of entry (e.g. a lengthy bureaucratic approval process). Thus the monetary costs borne by the government in subsidizing entry may be lower than our estimates. Nonetheless, the key qualitative conclusions that entry subsidies are more wasteful than other subsidies (see Section 6) remain unchanged unless most entry subsidies (more than 90%) is non-monetary.

6 Evaluation of China's Industrial Policies

In this section, we carry out counterfactual experiments to evaluate the effects of China's industrial policies. Doing so necessitates simulating the industry for a long period of time, as both entry and investment have dynamic consequences – the accumulated capital remains productive and new firms can continue operation long after the policy ends.[33]

We implement the counterfactuals as follows. We simulate the world shipbuilding industry from 2006, when the Chinese government started subsidizing its domestic industry, until 2099 (the discounted profits post 2099 is negligible), *turning on and off the subsidies* as needed for each experiment.[34] In each period, Chinese firms make optimal production, investment, exit and entry

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[32]Entry subsidies are large in magnitude, amounting to RMB 330 billion in our sample period. While the number is large, it is consistent with a back-of-the-envelope calculation: entry subsidies induced the entry of 80-90 additional firms and each firm is worth a few billion RMB.

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

[34]For each counterfactual, we carry out 50 simulations and average over these simulations. Further increasing the number of simulations makes little difference to the results. The discount rate is 0.02 per quarter, or 0.08 annually, reflecting the high interest rates in China (averaging 6% from 1996 to 2018). We have experimented with different

decisions, taking both prices and government policies as given. Japanese and South Korean firms make production decisions, but do not invest or enter/exit, since there is limited capacity expansion or entry/exit among these firms as discussed above.[35] Equilibrium prices are determined each period by the intersection of the industry demand and supply curves. Appendix B contains more details on the implementation.

In Section 6.1, we first briefly evaluate the impact of subsidies. Then, we turn to our main exercise: the welfare evaluation of different types of subsidies. We also discuss the timing of subsidies. Section 6.2 evaluates the consolidation policies. Section 6.3 examines different rationales for industrial policy interventions.

6.1 Evaluation of Subsidy Policies

Magnitude of Subsidies Perhaps not surprisingly, subsidies had a significant impact on every outcome we examine: China's world market share, overall production, prices, entry and exit, investment, profits, concentration and capital utilization.

Total subsidies handed out to Chinese shipbuilders were close to RMB 540 billion (or $90 billion) between 2006 and 2013 without discounting, with the lion's share going to entry subsidies (RMB 330 billion), followed by production subsidies (RMB 159 billion) and investment subsidies (RMB 51 billion). The subsidies are massive in comparison to the size of the domestic industry, whose revenue was around RMB 1700 billion during the same period.

These subsidies increased China's world market share during 2006-13 by nearly 40%. The ascent in market share is most pronounced for bulk ships, since a large fraction of the new shipbuilders produce bulkers and the cost advantage enjoyed by Japanese and South Korean firms is narrower for bulkers. In the absence of subsidies, China's production would still increase in absolute value in response to the higher demand during the boom; this increase however would have been much less pronounced.

In absolute terms, only one-fourth of China's increased production translated into higher world industry output. The remaining three-fourths constitute business-stealing, whereby Chinese production expanded at the expense of competing firms in other countries. As a consequence of Chinese subsidies, South Korea's market share decreased from 47% to 38% and Japan's market share from 24% to 21% during the 2006-2013 period, with profits earned by shipyards in these two countries falling by RMB 140 billion.

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subsidy durations (subsidies ending after a varying number of decades) and different discount rates. The results are qualitatively very similar.

[35]In practice, Chinese subsidies might induce exit in Japan and South Korea, which could be important in the long-run and result in larger gains for China. On the other hand, our analysis does not take into account industrial policies that could be adopted by Japan and South Korea. If these governments respond in kind, the gains to Chinese shipbuilders from the subsidies would be reduced.

The rising global supply induced by the subsidies led to substantial reductions in global ship prices: the price of bulk ships, oil tankers, and containers fell by 8.2%, 6.2%, and 3.1% from 2006 to 2008, respectively (Table 10). The price effect is most significant for bulkers, as Chinese shipyards account for a bigger market share in bulk and demand for bulkers is the most inelastic. As the effect of past subsidies accumulates through an increased production capacity for existing firms and a larger number of new firms, the price drop became more pronounced from 2009 to 2013 and reached 16.5% for bulk, 10.6% for tankers, and 3.7% for containers. Because of the reduction in ship prices, world shipowners benefit by RMB 230 billion from Chinese subsidies, though only a small proportion of these gains accrues to Chinese shipowners as they account for a small fraction of the world fleet.[36]

Figure 7 compares the number of Chinese firms by year with and without subsidies. Government support more than doubled the entry rate: 148 firms enter with subsidies vs. 65 without subsidies from 2006 to 2013. It also depressed exit (37 firms exit vs. 46) and changed the composition of exiting firms. With subsidies, a bigger fraction of exiting firms come from those that entered during the policy period, partly because subsidies attract small and relatively inefficient firms.

Figure 9 illustrates the striking effect of subsidies on investment, which skyrocketed post 2006. Total investment during 2006-2013 is RMB 114 billion with subsidies, compared to RMB 42 billion without subsidies.

Finally, total subsidies handed out between 2006-13 led to an estimated RMB 145 billion increase in the discounted lifetime profits for Chinese shipbuilders. Entry subsidies induce entry of small inefficient firms. In addition, production and investment subsidies boost firms' variable profit and retain unprofitable firms that should have exited. As a result, the industry became much more fragmented post the policy period. China's domestic Herfindahl-Hirschman index (HHI) plummeted from 1,200 in 2004 to less than 500 in 2013 (Figure 8) with a significantly lower 4-firm concentration ratio. Despite a sizable increase in China's overall production, capacity utilization was much lower, particularly when demand was low. If China had not subsidized the shipbuilding industry, the ratio of production to capital (which proxies for capacity utilization) would have been 20% higher during the 2009-2013 recession.

Welfare Analysis and Effectiveness of Subsidies   Subsidies led to a substantial increase in the number of firms, capacity, and production, and also resulted in lower prices, lower capital utilization and a more fragmented industry structure. Our first goal in this section is to explore the welfare implications of the subsidies. Since there is no market failure that the subsidies address, these

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[36]According to Clarkson World Shipyard Monitor, orders by Chinese shipowners have been growing but still account for under 10% of world orders in 2010-2013.

interventions are necessarily welfare-reducing.[37] What is less well-understood is how distortionary subsidies are and the magnitude of the welfare losses. Our second, and perhaps more important goal is to shed light on the effectiveness of different types of policy instruments, in particular the relative efficacy of production, investment, and entry subsidies, and search for general lessons that can be applied in other contexts. Since China's domestic consumer surplus accounts for a small fraction of the world consumer surplus as discussed earlier, and is modest compared to the industry profit, we only briefly discuss the effect on consumer surplus when it is relevant.

In order to compare different types of policies, 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. When simulating the industry beyond 2013, we assume that the 2013 policy environment is propagated to the end of our simulation period unless otherwise noted. For example, in the scenario with all subsidies, entry subsidies run from 2006 to 2008, whereas production and investment subsidies run from 2006 to the end.[38]

The welfare effects are summarized in Table 11, which reports the discounted sums of industry revenue and profit in China, as well as the magnitude of different subsidies. The last three rows, "ΔRevenue/Subsidy", "Δ(Profit-Inv. Cost)/Subsidy", and "ΔNet Profit/Subsidy", constitute different measures of the effectiveness of the subsidies. "ΔRevenue" is the revenue difference between subsidies and no subsidies. We report the ratio between the revenue increase and the subsidy cost to evaluate the effectiveness of subsidies at promoting industry revenue. This is of interest, as China's official government documents explicitly state production targets for the domestic shipbuilding industry. "Δ(Profit-Inv. Cost)" is the difference in variable profit (revenue minus production cost) after subtracting investment costs. Finally, "ΔNet Profit" is the difference in net profit which equals revenue plus the scrap value upon exiting, minus the costs of production, investment, and entry. We use "ΔNet Profit/Subsidy" to measure the *gross rate of return* of different subsidies. A rate lower than 100% indicates that the cost of subsidies exceeds the net benefits to the domestic industry and that subsidies are welfare reducing.

When all subsidies are in place, this 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 56% for production subsidies, 87% for investment subsidies, and 24% for entry subsidies, respectively. This implies that the distortions induced by multiple subsidies are convex: i.e. the combination of all policies yields a considerably lower return compared to each policy in isolation. For example, 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-dollar terms.

An important factor contributing to the low returns are fixed costs. Indeed, 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: as exit is irreversible, firms are willing to suffer temporary losses in expectation of higher demand in the future. If fixed costs were zero, the rate of return on subsidies would increase from 18% to 29%.[39]

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. On average, one RMB increase in the production and investment subsidy raises the industry's revenue by RMB 1.8 and RMB 2.3, respectively. This might justify the popularity of these subsidies in China, since quantity and revenue targets are often linked to local officials' promotion (Jin et al., 2005). In addition, as discussed earlier, the government had set explicit output targets for ship production.

The investment subsidies appear less distortionary than the production subsidies (87% vs. 56%). However, this comparison is confounded by the larger magnitude of the production subsidies, as in our setting bigger subsidies are associated with more distortion. We reduce the per-unit production subsidies by 75% and make the total amount of these two subsidies comparable (RMB 44 billion). The return to investment subsidies remains higher, though the difference is smaller (87% vs. 81%). On the other hand, production subsidies are slightly more effective at increasing revenue: the increase in revenue per RMB of subsidy is 233% for production subsidies, versus 226% for investment subsidies. Thus, depending on the policymaker's objectives, there is potentially a trade-off between production and investment subsidies. If the policymaker's goal is to maximize industry profits, perhaps investment subsidies are superior. However, if the goal is to achieve a production/revenue target, then production subsidies might be preferred. In a similar vein, Aldy et al. (2018) find that wind farms claiming output subsidies produced 10-11% more power than wind farms claiming investment subsidies. Finally, for a government that cares about both industry revenue and profit, a mix of production and investment subsidies may be more effective.

Entry subsidies are the least efficient policy instrument among the three by a large margin.[40] This is because the take-up rate for production and investment subsidies is higher among firms that are more efficient, receive more orders (higher backlogs), and are more likely to invest.[41] In

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[39]The discussion here does not take into consideration the cost to finance these subsidies. Estimates from Ballard et al. (1985) suggest that collecting one dollar of government revenue costs 17 to 56 cents in the U.S. Including the cost to finance subsidies will further drive down the rates of return.

[40]It might be easier to finance entry subsidies than production or investment subsidies, which matters for the implementation of different policies. Unfortunately we do not have data to evaluate the importance of this concern.

[41]Appendix C uses a simple static model to compare production and investment subsidies and illustrates that the rate of return is higher when taken up by efficient firms. In our empirical analysis, there are four decisions that can be distorted: entry, production, investment, and exit. Compared to efficient firms, inefficient firms are more likely to be distorted in all four margins with subsidies. In addition, efficient firms enjoy considerable economies of scale as a

addition, production and investment subsidies increase backlogs and capital stocks that lead to scale economies and drive down both current and future production costs. In contrast, the entry subsidies predominantly attract the entry of small, high-cost firms that would not find it profitable to operate in the absence of subsidies. The large number of additional entrants contributes little to industry profits, while it reduces ship prices and exacerbates excess supply.

Table 12 illustrates these points by decomposing subsidies that are taken up by firms above or below the median efficiency (as measured by $\bar{s}_{jt}$, defined in equation 15). Subsidies are significantly more effective when given to productive firms, both in terms of revenue and in terms of profits. The subsidies accruing to productive firms has a net rate of return equal to 29%, while those going to unproductive firms is almost entirely wasted.[42] Note that production and investment subsidies are reasonably well-targeted, with between 70-84% of subsidies going to productive firms. In comparison, less than 50% of entry subsidies are taken up by productive firms.

Our welfare analysis so far has abstracted away from changes in consumer surplus enjoyed by Chinese shipowners. Assuming that these gains are equal to 10% of total surplus gains (which is an upper bound), the rate of return increases from 18% to 26%. For the total benefit of the subsidies to exceed the cost, China's share of the global consumer surplus from new ships would need to be over 94%.[43]

Finally, as a robustness check, we repeated our analysis assuming that firms are Cournot competitors rather than price takers. Parameter estimates are quantitatively similar to our main specification, though the estimated marginal costs become smaller and firm profits higher. Therefore, the recovered subsidies are somewhat larger (in the order of 10-20%). The counterfactual results, including both the return to industrial policies and the comparison of different subsidies, are unchanged in this case.

Business Cycles and Industrial Policy Like many other industries, cycles of booms and busts are a fundamental feature of shipbuilding. A rich macro and public finance literature explores the optimal fiscal policy over the business cycle and 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-run investment by lowering volatility (Aghion et al., 2014). It is less well-understood, however, how industrial policy should

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result of larger backlogs and capital stocks relative to inefficient firms, which further widens the wedge in efficiency.

[42]The rate of return for subsidizing unproductive firms is negative due to a general equilibrium effect: increased production drives down ship prices. Since these firms have high production costs, reduction in ship prices offsets potential gains in quantity produced.

[43]Naturally, these results depend on the elasticity of the demand curve. We repeat our counterfactuals by assuming that demand post 2006 is as elastic as pre 2006. We find that with a more elastic demand curve post-2006, the incidence of subsidies on producers is higher, resulting in a smaller reduction on prices, a smaller increase in consumer surplus, and a larger gain in producer surplus. As such, the return on subsidies would increase from 18% to 25%.

be optimally designed in the presence of boom-and-bust cycles.

To explore whether the effectiveness of subsidies varies over the business cycle, we carry out two counterfactual simulations. The first simulation only subsidizes production and investment of all firms during the 2006-08 boom, while the second simulation only subsidizes production and investment during the 2009-13 bust. All subsidies are discontinued afterwards. The subsidy rates are calibrated so that the government spends the same amount in the two scenarios. This design allows us to explore the long-run implications of pro-cyclical vs. counter-cyclical policies.

Strikingly, subsidizing firms during the boom leads to a net return of only 29%, whereas subsidizing firms during the downturn leads to a much higher return of 78%, as shown in Table 13. What explains this large difference?

There are two main contributing factors: convex production and investment costs, and firm composition. In booming periods, the industry is operating close to full capacity. Further expansion is costly and entails 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 idle. Subsidies mobilize underutilized resources, resulting in smaller distortions. The second contributing factor is the changing firm composition over the business cycle. Subsidies during a boom attract a higher fraction of inefficient firms, which pushes down the rate of return. As an illustration, Figure 10 plots the average $\bar{s}_{jt}$ (a measure of profitability) over time for these two scenarios. Subsidies in the boom leads to a much lower average profitability than subsidies in the bust, as expected.

Despite the benefits of a counter-cyclical policy, the actual policy mix is overwhelmingly pro-cyclical: RMB 442 billion of subsidies were handed out between 2006 and 2008, vs. RMB 106 billion 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, political considerations, etc. (Tornell and Lane, 1999; Barseghyan et al., 2013).

6.2 Evaluation of Consolidation Policies

One explicit goal of China's industrial policies after the financial crisis is to facilitate consolidation and create large successful firms that can compete against international conglomerates. A crucial policy for achieving this objective was the 2013 *Shipbuilding Industry Standard and Conditions*, whereby the government announced a list of selected firms that meet the industry standard, the so called "White List". In this section, we ask the following questions. First, does the consolidation policy improve the return of subsidies, and if so by how much? Second, did the government choose the optimal set of firms for the White List?

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Gains from Targeting   In our first counterfactual exercise, we rank firms in 2013 based on their expected variable profits ($E[\pi_{jt}]$) in that year, and select the top 56 firms with the highest profitability to form the White List.[44] These firms receive production and investment subsidies, while other firms receive no subsidies post 2013. We compare this policy to the one that subsidizes all firms after 2013, as well as the case with no subsidies.

As shown in Table 14, directing subsidies towards the best set of firms generates *considerable* gains. The net rate of return for targeted production and investment subsidies is 84%, whereas the return is 38% when all firms are subsidized. This pattern holds across all three measures of policy effectiveness (revenues, profits net of investment cost, net profits), 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, subsidizing existing firms leads to lower exit than is socially optimal, but the set of firms on the White List is less likely to be subject to sub-optimal exit decisions, in contrast to other firms that are more prone to distortions. Lastly, as argued above, targeting productive firms leads to less distortion.

White List   While subsidies are less distortionary when targeted towards efficient firms, it is unclear a priori whether the government targeted the optimal set of firms. Information asymmetries and regulatory capture might bias the process in favor of interest groups or "sunset sectors" (Lane, 2017).

To avoid confounding effects from subsidies and focus on the "White List" only, in this analysis we discontinue all subsidies post 2013 and examine profits post 2013 for the actual set of firms on the White List vs. firms included in our "optimal White List" as constructed above. Note that our selection criterion focuses on short-run profitability and thus we may not choose the firms with the highest long-run profits. Thus this is a weak test: if the government chose the set of firms with the highest long-run profitability, then their selected firms should do at least as well as the set of firms we choose.

As shown in Figure 11, industry profits are significantly lower with the actual White List (the dashed blue line) than our "optimal White List" (the solid red line). The difference in the long-run industry profits and revenue (the discounted sum from 2014 to 2099) is 14% and 10%, respectively, suggesting that the government did not choose the optimal set of firms in its White List. Out of the 56 firms chosen by the government, only 31 firms appear in our White List based on the short-run profitability. There appears a bias in favor of SOEs: 65% of firms selected by the government are SOEs, while 55% of our selected firms are SOEs.

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[44]Four out of sixty firms on the official White List cannot be matched to the rest of our datasets described below, hence we focus on the remaining fifty-six firms in our counterfactual analysis.

6.3 Rationales for Industrial Policy

Our evaluation of China's industrial policy in promoting the shipbuilding industry so far is mixed. The subsidies boosted production and investment, but contributed to the development of a fragmented industry, reduced the capital utilization rates, and to a large extent, were dissipated through sub-optimal entry/exit decisions. In this section, we assess traditional arguments in favor of industrial policies and evaluate the extent to which existing policies are effective in achieving these objectives.

A common rationale for industrial policy is related to economies of scale: in markets with large entry costs or other entry barriers, the government may want to boost, or aid the formation of a sector through subsidies. Indeed, especially in developing countries, capital market inefficiencies and other regulatory constraints may drive a wedge between privately and socially optimal firm entry (WTO, 2006). China provided entry subsidies in a number of sectors, which led to a large number of small firms, before implementing consolidation policies to reduce industry fragmentation. A combination of subsidies in the initial periods of the industry, possibly followed by consolidation, could facilitate firm entry, induce a high industry growth rate, and allow the survival of the best performing firms post consolidation.

We assess this argument by simulating two scenarios. In the first scenario, the government subsidizes entry, production, and investment from 2006 to 2013, chooses the 56 best firms from the pool in 2014, and shuts down the remaining firms. In the second scenario, the industry evolves without any intervention and then the government selects the same number of the best firms in 2014. In both scenarios, once the White List firms have been selected and the other firms removed, the industry is allowed to evolve with no further government intervention. We compare the long-run industry revenue and profits from 2014 onward.

Subsidizing the industry prior to consolidation does lead to 18% higher long-run industry revenue and profits, as shown in Figure 11. Since the number of firms is the same upon consolidation in 2014, the profit difference is driven by firm composition: firms are bigger and more productive with subsidies (solid red line) than in the scenario without subsidies (dashed green line). Nonetheless, the increase in the long-run industry profit is only 34% of the cost of subsidies from 2006 to 2013. Therefore, this argument does not provide a compelling justification for subsidizing the industry. In particular, entry subsidies are especially costly when combined with consolidation because a lion's share of the entry subsidies goes to waste when new entrants exit post consolidation.

Another justification for subsidies is the presence of positive externalities (such as industry-wide learning-by-doing), as each firm produces less than what is socially optimal. As we discussed in Section 5.1, there is no evidence of significant spillover effects in this industry. This is consistent with industry reports that much of the production by Chinese shipyards occurs in product sectors

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with mature technologies, where the scope for learning is limited.[45]

Our analysis focuses on the shipbuilding sector and does not account for benefits to other sectors. While spillovers to downstream sectors provide a rationale for subsidizing upstream industries (Liu, 2018), it is unlikely a justification for subsidies in the shipbuilding industry. Three-quarters of the output from this industry is used for final consumption (China's 2012 Input-Output Table). Moreover, most of these ships are exported, reducing the share of benefits from subsidies that is captured domestically.

There are potential spillovers to upstream sectors. Intermediate inputs from other sectors account for 63% of the value of ships produced. Steel in particular is an important input. One might argue that shipbuilding subsidies are partially designed to boost demand for steel, a strategic sector that has been 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).

Another justification for industrial policy is labor market consequences: subsidies could 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 and marine equipments, etc.) accounts for less than 0.5% of national employment, suggesting that any potential labor market benefits would be modest.

In the presence of market power, there are in principle strategic trade benefits from subsidizing industries that compete with foreign firms (Krugman, 1986; Brander, 1995). Our main findings remain unchanged when we allow for firms to exercise market power in Cournot competition; indeed the returns to subsidies are nearly indistinguishable. For strategic trade considerations to be relevant, a necessary condition is the existence of market power and thus 'rents on the table' that can be shifted from foreign companies to domestic firms. Given the fragmented nature of the industry where the largest firm accounts for less than 5% of the market, our results suggest that the shipbuilding industry is unlikely an effective target for strategic trade policies.

Given China's prominent role in global trade, another reason to subsidize shipbuilding may be to boost its import and export sectors. Indeed, a larger worldwide fleet reduces transportation costs and thus increases trade; if Chinese exporters and importers face entry barriers or other frictions, these subsidies may be justifiable. To evaluate this argument, we would have to augment our model with a general equilibrium model of trade in order to predict changes in China's exports and imports brought by the enlarged ship fleet due to the industrial policy; unfortunately this creates complications, such as computing the corresponding welfare gains, that fall beyond the scope of this paper.[46]

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[45]There 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 our tests lack statistical power.

[46]In particular, to perform this calculation we need to compute the change in freight rates after the subsidies (Kaloupt-

Finally, it is worth noting that other considerations, including national security and military implications, as well as the desire to be the world leader in heavy industries (as stated in various government documents), might be equally relevant in motivating these policies. Regardless of the motivation, our analysis provides cost estimates (and welfare losses) and the relative efficacy of implementing these policies that can be used as a guidance for future polices.

7 Conclusion

We empirically evaluate China's industrial policies, using the shipbuilding industry as a case study. While subsidies led to a significant increase in China's world market share and buttressed China's ascent into global influence, they are wasteful and entail substantial welfare distortions. Counterfactual simulations indicate that the effectiveness of subsidies can be improved substantially when targeted towards more productive firms or implemented counter-cyclically. Our results provide a cautionary tale of industrial policies implemented in developing countries and highlight the importance of a proper policy design.

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sidi 2018 calculates this at 3-5% in the case of Handysize vessels), the trade elasticity with respect to freight rates (Brancaccio et al. 2018 calculate this to be about 1), China's total *maritime* trade (the exact portion of China's trade that is carried by ships, which is unknown) and finally, the resulting gains from trade. It is the latter element that is complicated and requires overlaying our framework with a GE trade model.

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Figure 1: China's Expansion in Major Industries

Total output: Bill RMB
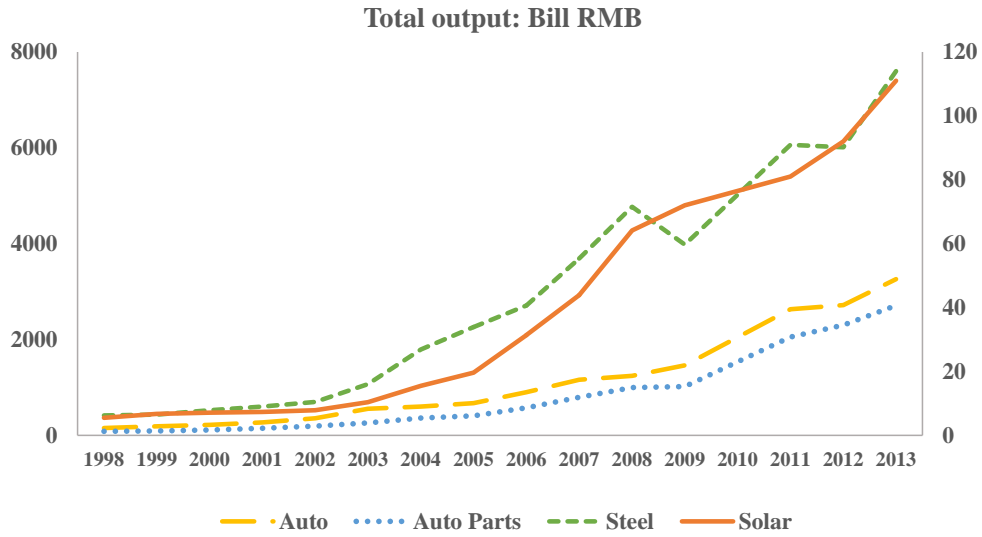
Source: NBS. The output of the auto, auto parts and steel industries are plotted on the left vertical axis, while the output of the solar industry is plotted on the right vertical axis.

Figure 2: China's Market Share Expansion
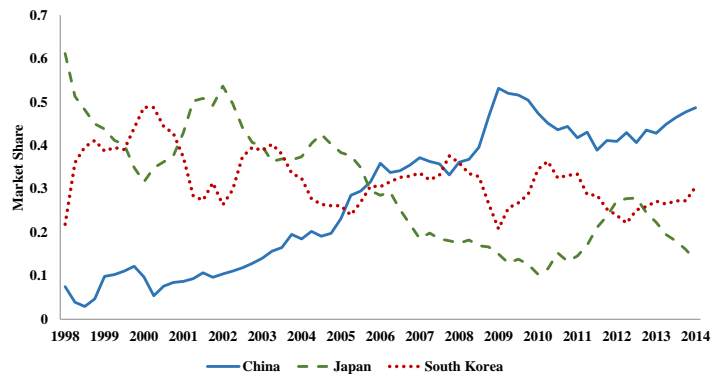
Source: Clarkson Research. Market shares computed from total quarterly ship orders.

Figure 3: Entry of New Shipyards
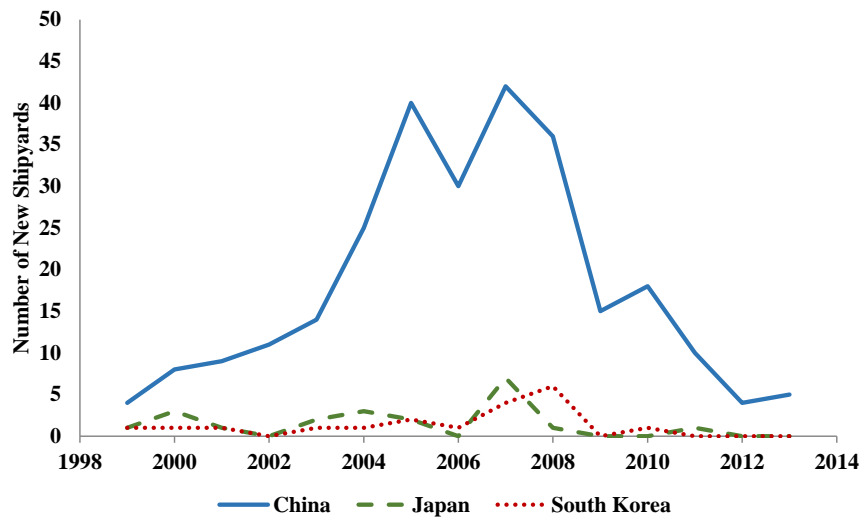
Source: Clarksons Research. Number of new shipyards.

Figure 4: Quarterly Investment by Chinese Shipyards
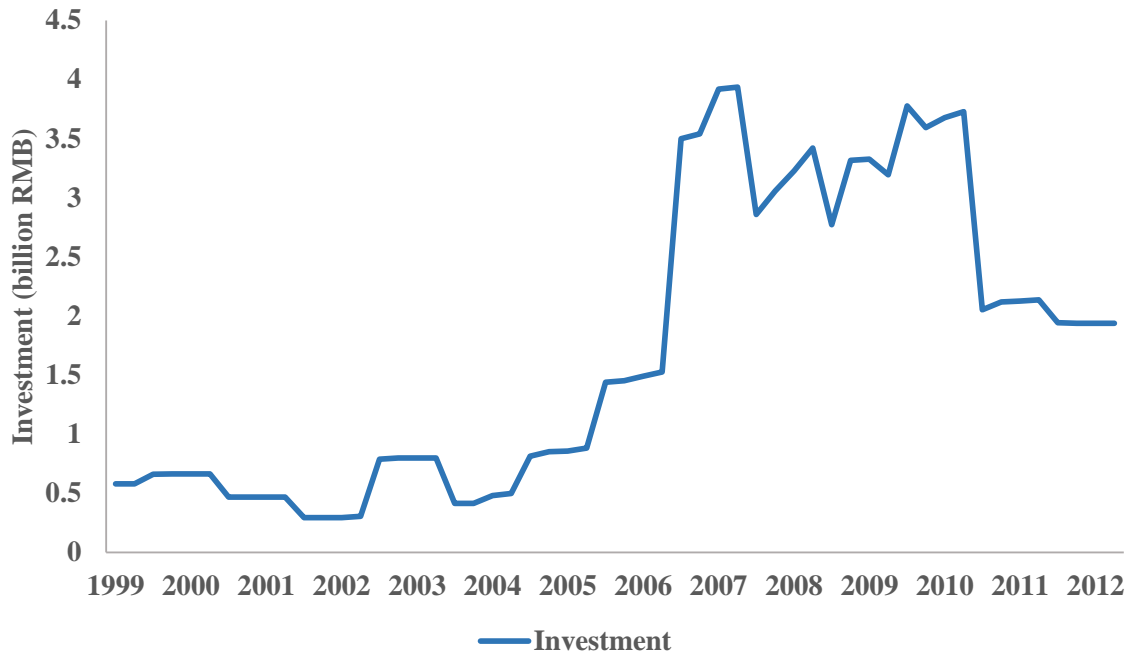
Source: NBS. Total quarterly investment.

Figure 5: Ship Prices
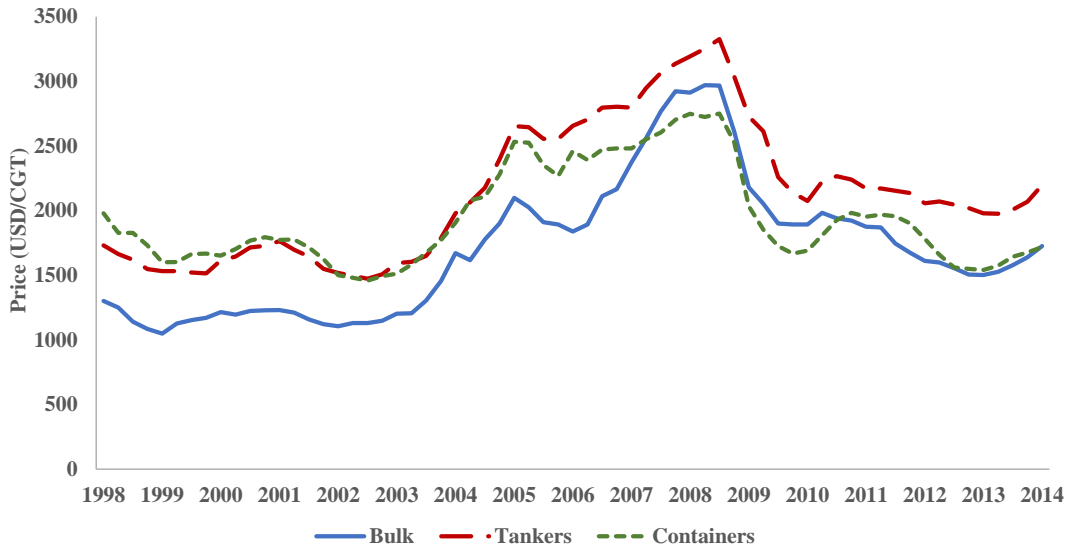
Source: Clarksons Research. Average price in US dollars per CGT.

Figure 6: Simulated vs. actual investment
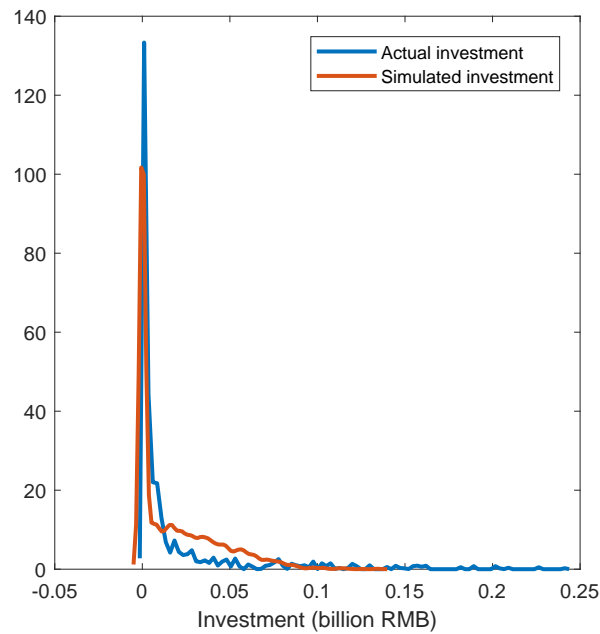
Note: For the simulated investment employed in the model, we use the estimated investment cost parameters and value function, randomly draw v for every observation, and calculate optimal investment.

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Figure 7: Number of firms, with and without subsidies
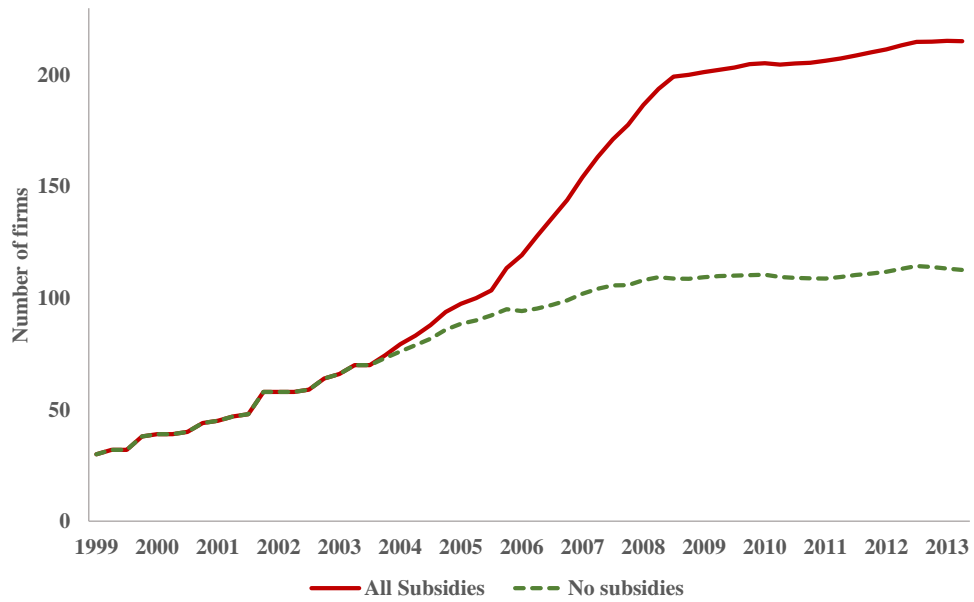
Note: Total number of firms in the case of all subsidies (as in the data) and a counterfactual case with no subsidies.

Figure 8: HHI for Chinese Shipbuilding, with and without subsidies
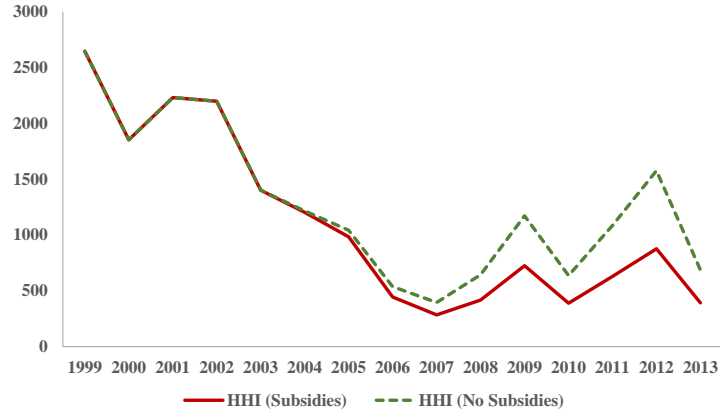
Notes: The HHI reported in the above figure is calculated using all Chinese yards in any given year. It is thus a measure of concentration within the Chinese shipbuilding industry.

Figure 9: Investment, with and without subsidies
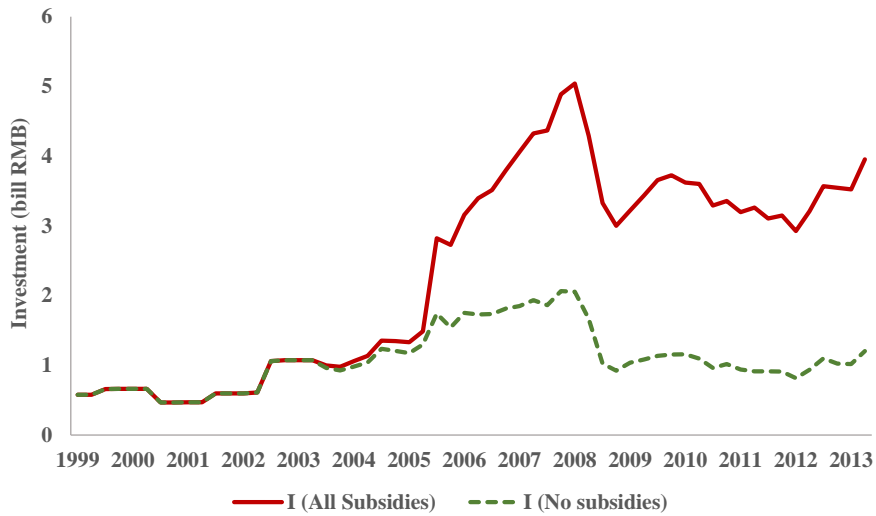
Note: Total investment in the case of all subsidies (as in the data) and a counterfactual case of no subsidies.

Figure 10: Average firm cost-efficiency $\bar{s}_{jt}$ with subsidies during the boom vs. subsidies during the bust
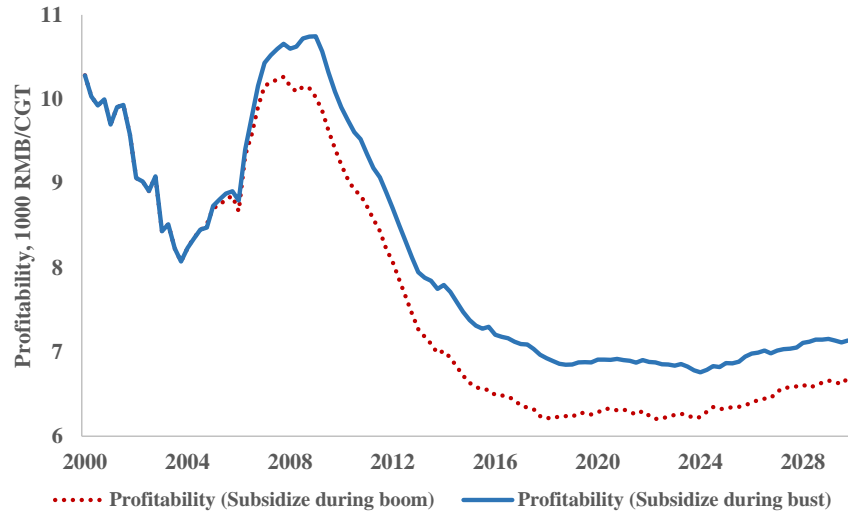
Note: Average firm cost-efficiency, as captured by $\bar{s}_{jt}$, when subsidies are distributed during a boom vs. during a bust. Variable $\bar{s}_{jt}$ is defined in Section 4.2.1.

Figure 11: Industry Profits Under Different White Lists
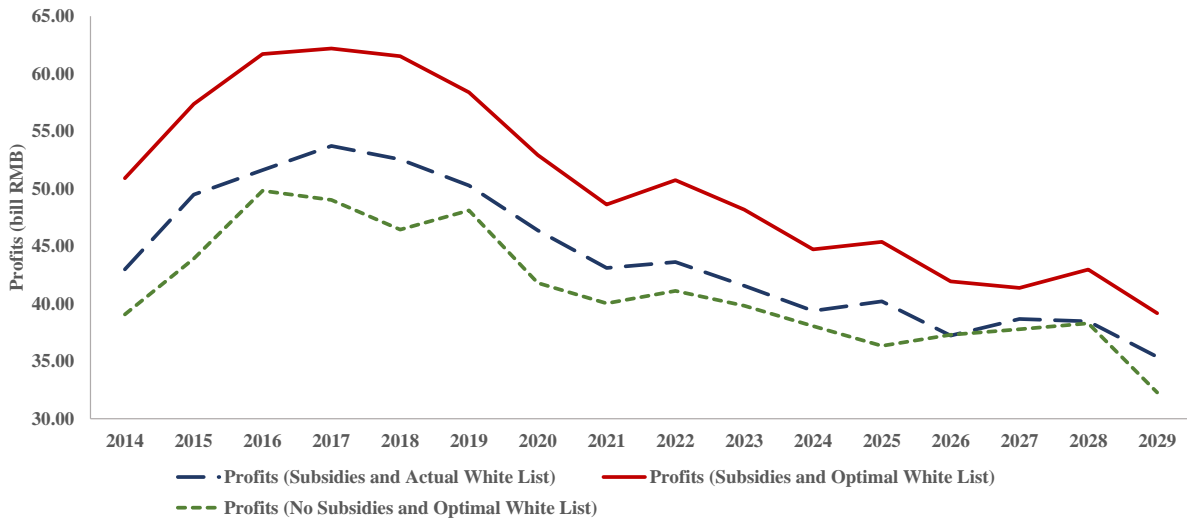
Note: In all scenarios, we pick a set of firms in the White List in 2013 and force all other firms to exit. In the scenario "Subsidies and Actual White List", the government subsidizes the industry until 2013 and then keeps the observed White List. In the scenario "Subsidies and Optimal White List", the government subsidizes the industry until 2013 and then chooses a White List based on observed profitability. In the scenario "No Subsidies and Optimal White List", the industry does not receive any subsidies, and in 2013 a White List of firms is selected based on observed profitability.

Table 1: Shipbuilding National Industrial Policies

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

Table 2: Summary Statistics

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

[1.] The data on orders and backlog is for yards in China, Japan and Korea. There are a total of 14,455 observations, out of which 7,186 are for Chinese yards, 5,448 are for Japanese yards and 1,821 are for Korean yards.

[2.] 10,101 observations are for yards that produce bulkers, 10,583 observations are for yards that produce tankers, and 4,813 observations are for yards that produce containerships.

[3.] We observe investment and capital only for Chinese yards.

Table 3: Demand estimates

Dependent variable:	(1) Orders	(2) Orders	(3) Orders	(4) Orders
Price (bulk)	-2.34***	-1.67***	-2.07***	-2.12***
	(0.77)	(0.64)	(0.69)	(0.75)
Price (tanker)	-2.66***	-1.46*	-1.80**	-1.76**
	(0.60)	(0.88)	(0.78)	(0.89)
Price (container)	-4.85***	-2.44***	-3.39***	-3.39***
	(0.91)	(0.85)	(1.01)	(0.99)
Price*Post2006	1.34***	1.00***	1.15***	1.34**
	(0.18)	(0.14)	(0.15)	(0.55)
Backlog (log)	0.34	-1.00***	-0.78**	-0.81**
	(0.25)	(0.33)	(0.38)	(0.37)
Freight rate (bulk)	2.84***	3.27***	3.35***	3.33***
	(0.45)	(0.56)	(0.57)	(0.56)
Freight rate (tanker)	4.04***	3.24***	2.94***	2.91***
	(0.70)	(0.68)	(0.65)	(0.65)
Freight rate (container)	6.45***	4.47***	4.69***	4.60***
	(0.87)	(0.73)	(0.77)	(0.75)
US Wheat price		-0.12	-0.10	-0.12
		(0.48)	(0.48)	(0.49)
Iron ore imports, China		2.62***	2.93***	3.01***
		(0.90)	(0.89)	(0.92)
Middle East refinery production		1.37	1.84*	1.66*
		(1.05)	(0.97)	(0.99)
World Car Trade		1.32***	2.08***	2.05***
		(0.44)	(0.49)	(0.49)
Trend			-0.026**	-0.020
			(0.011)	(0.019)
Trend*Post2006				-0.0026
				(0.0076)
R^2_bulk	0.68	0.71	0.71	0.71
R^2_tanker	0.26	0.33	0.35	0.36
R^2_container	0.44	0.52	0.51	0.51

[*] N equals 64 for bulk and container and 61 for tankers. The freight rate is the Baltic Exchange Freight Index for bulk ships, Baltic Exchange Clean Tanker Index for tankers, and the Containership Timecharter Rate Index for containerships. The demand shifters include the US wheat price and total Chinese iron ore imports for bulk, Middle East refinery production for tanker, and world car trade for containership. We instrument ship prices using steel production and the steel ship plate price. Parameters are estimated using GMM.

Table 4: Cost function estimates

	Bulk		Tanker		Container	
Type-specific	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
β_q	7.34	9.52	13.60	5.54	9.69	5.63
σ_ω	8.49	10.43	14.40	7.08	12.14	5.71
Constant (1000 RMB/CGT)	19.26	15.88	36.58	9.18	32.30	8.39
Steel Price (1000 RMB/Ton)	1.55	7.49	1.10	3.04	0.63	1.65
Capital (bill RMB)	-2.43	-2.96	-2.61	-1.80	-2.19	-2.01
Capital^2	0.19	0.83	0.06	0.25	0.06	0.32
Backlog	-1.56	-5.29	-4.44	-5.04	-2.88	-3.34
Backlog^2	0.07	4.04	0.24	3.43	0.18	1.97
Backlog of Other Types	0.13	0.94	0.35	1.65	0.46	2.66
Common						
2006-2008	-1.51	-2.62				
2009+	-1.38	-2.37				
Large firms	-3.85	-6.97				
Jiangsu	-2.64	-4.75				
Zhejiang	-1.42	-2.80				
Liaoning	-1.87	-2.05				
CSSC/CSIC	-0.77	-1.20				
Private	0.14	0.30				
Foreign JV	-0.78	-1.45				
Age	0.18	3.14				
N	4886		4977		2504	

[*] Standard errors bootstrapped using 500 bootstrap samples.

Table 5: Cost function estimates, pooling data across China/Japan/South Korea

Type-specific	Bulk		Tanker		Container	
	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
MC (thousand RMB / CGT)						
β_q	9.10	12.94	11.04	9.36	5.06	7.22
σ_ω	10.36	13.78	15.12	11.11	13.36	9.20
China (1000 RMB/CGT)	19.40	17.11	32.30	12.99	29.79	12.68
Japan (1000 RMB/CGT)	12.57	16.67	30.92	12.78	25.02	11.45
South Korea (1000 RMB/CGT)	15.92	14.88	23.07	12.01	19.83	11.13
Steel Price (1000 RMB/Ton)	2.12	14.20	2.46	8.80	1.89	6.25
Capital (bill RMB)	-2.92	-3.06	-2.06	-1.55	-1.41	-1.33
Capital^2	0.23	0.89	-0.01	-0.05	-0.03	-0.14
Backlog	-2.09	-6.63	-4.50	-6.38	-3.06	-4.40
Backlog^2	0.10	4.83	0.24	4.15	0.19	2.48
Backlog of Other Types	0.11	0.76	0.32	1.47	0.47	2.66
Common						
China 2006-2008	-2.79	-4.57				
China 2009+	-0.90	-1.56				
Large firms	-4.17	-6.84				
Jiangsu	-2.93	-4.81				
Zhejiang	-1.57	-2.79				
Liaoning	-1.87	-1.88				
CSSC/CSIC	-0.93	-1.28				
Private	0.13	0.24				
Foreign JV	-0.92	-1.61				
Age	0.26	6.14				
N	10013		10429		4661	

* Standard errors bootstrapped using 500 bootstrap samples. We pool together Chinese/Japanese/Korean yards. We observe the capital stock only for Chinese yards. To account for the missing values, we set the capital variable to zero for Japanese and Korean yards, and allow the constant term to differ by country. We also allow the backlog coefficients to differ by country. (Backlog coefficients for Japan and Korea are not reported above).

Table 6: Estimates of investment cost and scrap value parameters

	Coeff.	T-stat
σ_ϕ	0.69	11.76
c1	1.00	
c2	21.72	10.57
c3	1.55	8.27
$c4_{2006-08}$	-0.25	-1.89
$c4_{2009+}$	-0.49	-4.07
N	4286	

[*] Standard errors bootstrapped using 500 block bootstrap samples.

Table 7: Actual vs. Simulated Exit

	1999-2005	2006-2013	Total
Actual exits	5	43	48
Simulated exits	9	30	39

[1] We simulate the model 50 times from 1999 to 2013 under the baseline assumptions, and report the average number of exits across these simulations in the table above.

Table 8: Entry Cost Distribution (Mean), billion RMB

	κ_{pre}	$\kappa_{post,06}$	% of pre costs	$\kappa_{post,09+}$	% of pre costs
Jiangsu	60	22	36%	69	114%
Zhejiang	91	37	41%	194	214%
Liaoning	56	29	51%	-	-
Other	25	10	38%	44	172%

[1] κ_{pre} refers to the mean of the entry cost distribution prior to 2004 for Zhejiang, and prior to 2006 for Jiangsu, Liaoning and Other regions.
[2] $\kappa_{post,06}$ refers to the mean of the entry cost distribution between 2006 and 2008 for Jiangsu, Liaoning and Other regions and between 2004 and 2008 for Zhejiang.
[3] $\kappa_{post,09+}$ refers to the mean of the entry cost distribution from 2009 onwards.
[4] We assume that $\bar{N}$, the number of potential entrants, equals twice the maximum number of potential entrants ever observed in the region.

Table 9: Actual vs. Simulated Entrants

	Pre	Post, Until 2008	Post, 2009+	Total
Actual entries	83	122	39	244
Simulated entries	69	125	38	232

[1] "Pre" refers to the period prior to 2004 for Zhejiang, and prior to 2006 for Jiangsu, Liaoning and Other regions.

[2] "Post, Until 2008" refers to the period between 2004 and 2008 for Zhejiang and between 2006 and 2008 for Jiangsu, Liaoning and Other regions.

[3] "Post, 2009+" refers to the period from 2009 onwards.

[4] We simulate the model 50 times from 1999 to 2013 under the baseline assumptions, and report the average number of entries across these simulations in the table above.

Table 10: Impact of Subsidies on Ship Prices

	Bulk	Tanker	Container
Subsidies, 2006-08	16.3	20.0	17.2
No subsidies, 2006-08	17.6	21.2	17.7
% difference	8.2%	6.2%	3.1%
Subsidies, 2009-13	8.8	8.1	9.2
No Subsidies, 2009-13	10.2	9.0	9.5
% difference	16.5%	10.6%	3.7%

[1] Prices in 1000 RMB/CGT

Table 11: Comparison of Different Subsidies

	All Subsidies	Only Production	Only Investment	Only Entry	No Subsidies
Lifetime Revenue 2006-	2320	2091	1796	1830	1696
Lifetime Profits 2006-	854	788	618	590	570
Production subsidies	256	216	0	0	0
Investment subsidies	86	0	44	0	0
Entry subsidies	302	0	0	171	0
Δ Revenue/Subsidy	97%	183%	226%	78%	
Δ (Profit-Inv. Cost)/Subsidy	44%	93%	148%	11%	
Δ Net Profit/Subsidy	18%	56%	87%	24%	

[1] Each element in the table refers to the discounted sum from 2006 to 2099, averaged across all simulations. For example, "Lifetime Profits 2006" refers to the discounted sum of profits earned by firms from 2006 to 2099.

[2] ΔRevenue/Subsidy equals the discounted sum of revenue in the scenario minus the discounted sum of revenue in the scenario with no subsidies, divided by the discounted sum of subsidies.

[3] (Profit-Inv.Cost) refers to profits net of the cost of investment. Δ(Profit-Inv.Cost)/Subsidy equals the discounted sum of (profits-investment cost) in the scenario minus the discounted sum of (profits-investment cost) in the scenario with no subsidies, divided by the discounted sum of subsidies.

[4] Net Profit = (Profits-Investment Cost+Scrap Value-Entry Cost). ΔNet Profit/Subsidy equals the discounted sum of net profits in the scenario minus the discounted sum of net profits in the scenario with no subsidies, divided by the discounted sum of subsidies.

[5] In the scenarios "Only Production", we maintain the same production subsidy as in the baseline estimation, but shut down entry and investment subsidies. The scenarios "Only Investment" and "Only Entry" are constructed in a similar fashion.

[6] We assume for each scenario that the government policy from 2014 onwards remains frozen at the 2013 policy. This implies in particular that in the "Only Production" and "Only Investment" scenarios, the government continues to subsidize firms beyond 2013, whereas in the "Only Entry" scenario, there are no entry subsidies beyond 2013 (reflecting the fact that the government had already discontinued entry subsidies by 2013).

Table 12: Effect of subsidies on productive and unproductive firms

	Unproductive firms	Productive firms
Lifetime Revenue 2006-	406	1911
Lifetime Profits 2006-	70	779
Production subsidies	40	215
Investment subsidies	26	60
Entry subsidies	157	146
Δ Revenue/Subsidies	71%	113%
Δ (Profit-Invest Cost)/Subsidies	19%	58%
Δ Net Profit/Subsidies	-4%	29%

[1] We define "unproductive" firms as firms with initial $\bar{s}_{jt}$ (at the time the policy change first occurred) below the median, and "productive" firms as firms with initial $\bar{s}_{jt}$ above the median.

[2] Each element in the table refers to the discounted sum from 2006 to 2099, averaged across all simulations. For example, "Revenue" refers to the discounted sum of scrap values earned by exiting firms from 2006 to 2099.

[3] ΔRevenue/Subsidy, Δ(Profit-Inv.Cost)/Subsidy and ΔNet Profit/Subsidy are defined as in Table 11.

Table 13: Pro-cyclical vs. counter-cyclical industrial policy

	Subsidize during boom	Subsidize during recession
Lifetime Revenue 2006-	1792	1795
Lifetime Profits 2006-	609	624
Production Subsidies	34	35
Investment Subsidies	16	16
Δ Revenue/Subsidies	222%	225%
Δ (Profit-Invest Cost)/Subsidies	86%	126%
Δ Net Profit/Subsidies	29%	78%

[1] In the policy "Subsidize during recession", the government offers subsidies during the recession of 2009-13, but offers no subsidies before 2009 or after 2013. In the policy "Subsidize during boom", the government offers production and investment subsidies during the boom of 2006-08, but discontinues the subsidies from 2009 onwards. The subsidy rates during the 2006-08 boom are adjusted downwards to match the amount handed out during the recession. Finally, no entry subsidies are offered in either scenario.

[2] Each element in the table refers to the sum from 2014 to 2099, discounted back to 2006, averaged across all simulations. For example, "Scrap Value" refers to the discounted sum (in 2006) of scrap values earned by exiting firms from 2014 to 2099.

[3] ΔRevenue/Subsidy, Δ(Profit-Inv.Cost)/Subsidy and ΔNet Profit/Subsidy are defined as in Table 11.

Table 14: Targeting subsidies to White List firms

	Subsidize All Firms After 2013	Subsidize White List firms After 2013	No Subsidies After 2013
Lifetime Revenue 2014-	945	887	736
Lifetime Profits 2014-	416	395	278
Production subsidies	129	88	0
Investment subsidies	48	16	0
Entry subsidies	0	0	0
Δ Revenue/Subsidies	118%	144%	
Δ (Profit-Invest Cost)/Subsidies	83%	109%	
Δ Net Profit/Subsidies	38%	84%	

[1] Each element in the table refers to the sum from 2014 to 2099, discounted back to 2006, averaged across all simulations. For example, "Lifetime Profits 2014-" refers to the discounted sum (in 2006) of profits earned by firms from 2014 to 2099.

[2] ΔRevenue/Subsidy, Δ(Profit-Inv.Cost)/Subsidy and ΔNet Profit/Subsidy are defined as in Table 11.

Appendix

Online Appendix. Not for Publication.

This appendix discusses the calibration of the fixed production cost, details for the dynamic estimation (e.g., estimates of the first-stage policy functions and state-variable transitions), and implementation of the counterfactual analyses.

A   Estimation Details

A.1   Calibrating the Fixed Cost

The NBS data include information on operating costs, which allows us to calibrate the fixed cost of production. A firm's total production cost is equal to:

$$C_{jt} = c_0 + C(q_{jt})$$

where $C(q_{jt})$ is the variable cost of taking q_{it} orders that is estimated from the Clarkson data, as discussed in Section 4.1.

Let C_{jt}^{NBS} denote the accounting operating costs, which include the costs of both ship production and ship repairs, a common practice in this industry. We follow the standard assumption in the production literature that the cost share of ship production is the same as its revenue share and obtain the accounting operating cost of ship production as:

$$\hat{C}_{jt} = C_{jt}^{NBS} * (R_j^{Clarkson} / R_j^{NBS})$$

where $R_j^{Clarkson} = \sum_t R_j^{Clarkson}$ denotes j's lifetime revenue from building new ships that is reported in Clarkson and $R_j^{NBS} = \sum_t R_{jt}^{NBS}$ denotes its lifetime revenue in NBS.

We use two approaches to estimate the fixed cost c_0; both deliver similar results. The first approach uses the quarters with zero production (so that the variable production cost is zero) and the accounting costs $\hat{C}_{jt}$ (after adjusting for repairs) in the same periods to infer the fixed cost. The second approach uses the difference between a shipyard's average operating costs and the average estimated variable cost of production:

$$c_0 = \frac{1}{T} \sum_t [\hat{C}_{jt} - C(q_{jt})]$$

Note that the calibrated fixed cost of operation is the same for all firms. While in principle we could allow the fixed cost to vary by firm characteristics, our data is not rich enough to deliver a precise estimate.

A.2   Testing for learning-by-doing in ship production

In this subsection, we examine evidence of learning-by-doing by shipyards. First, we evaluate within-firm learning-by-doing by allowing a firm's marginal cost to depend on its cumulative past production. As shown in Table A1, a larger past production leads to higher marginal costs, which is inconsistent with there being any within-firm learning-by-doing. Second, we allow a firm's marginal cost to depend on the industry cumulative output, as a crude test of industry-wide learning-by-doing (where firms learn from each other). Without instrumenting for the industry cumulative output, this exercise is likely to over-estimate spillover effects: if there are common unobserved shocks that raise the output of all firms, it will look as though there are positive spillover effects. Despite this, we find limited evidence for spillover effects, as we can see in the third panel of Table A1. Marginal costs increase with the cumulative industry production for tanker and container and only modestly decrease with the cumulative industry production for bulk, though none of these coefficients is statistically significant.

Table A1: Cost function estimates, pooling data across China/Japan/South Korea

	Bulk		Tanker		Container	
Type-specific	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
Baseline specification						
Capital (bill RMB)	-2.92	-3.06	-2.06	-1.55	-1.41	-1.33
Backlog	-2.09	-6.63	-4.50	-6.38	-3.06	-4.40
Allow for within-firm learning						
Capital (bill RMB)	-1.94	-2.12	-1.95	-1.52	-1.11	-1.22
Backlog	-1.45	-5.05	-4.41	-5.06	-0.90	-1.30
Cumulative Q	0.07	4.72	0.09	5.59	0.01	4.00
Allow for within-firm and industry-wide learning						
Capital (bill RMB)	-2.04	-2.16	-3.41	-1.69	-2.04	-1.32
Backlog	-1.35	-4.58	-6.60	-4.02	-1.58	-1.16
Cumulative Q	0.08	4.76	0.13	4.39	0.02	2.94
Cumulative Q, China	-0.03	-1.60	0.18	1.47	0.33	1.30

[*] Standard errors bootstrapped using 500 bootstrap samples. We pool together Chinese/Japanese/Korean yards. We observe the capital stock only for Chinese yards. To account for the missing values, we set the capital variable to zero for Japanese and Korean yards, and allow the constant term to differ by country. We also allow the backlog coefficients to differ by country. Backlog coefficients for Japan and Korea are not reported above.

[*] The first panel repeats key coefficients from the specification reported in Table 5. The second panel includes all regressors from the specification in Table 5, as well as each firm's cumulative past production. The third panel includes all regressors from the specification in Table 5, each firm's cumulative past production, and the country's cumulative past production.

A.3 Estimating the Investment Policy Function

Here we discuss the robustness check for the first stage investment policy function that is based on the CLAD estimator discussed in Section 4.2.1. The investment policy function is assumed to be additive in the observed state variables and the unobserved investment cost shock:

$$I_{jt}^* = h_1(s_{jt}) + h_2(v_{jt})$$
$$I_{jt} = max(I_{jt}^*, 0)$$

where the second equation makes it explicit that investment is non-negative. Powell (1984) showed that we can recover $h_1(s)$ through the Censored Least Absolute Deviations estimator (CLAD) while normalizing the median of $h_2(v_{jt})$ to 0. Once we obtain the CLAD estimate $\hat{h}_1(s)$, we treat $I_{jt} - \hat{h}_1(s_{jt})$ as data with the goal of estimating $h_2(v_{jt})$ with the truncated data:

$$\tilde{i}_{jt} \equiv I_{jt} - \hat{h}_1(s_{jt}) = max(h_2(v_{jt}), -\hat{h}_1(s_{jt})), \text{or}$$
$$\tilde{i}_{jt} = max(h_2(v_{jt}), \bar{h}_{jt})$$

where in the second equation we use $\bar{h}_{jt}$ to denote $-\hat{h}_1(s_{jt})$.

Note that the level of truncation $\bar{h}_{jt}$ varies across observations. We use the observed probability of truncation (zero or negative investment) to back out the level of the investment shock that induces truncation, conditioning on the observed state variables (let Φ denote the CDF of a standard normal):

$$Pr(\tilde{i}_{jt} > \bar{h}_{jt} | \bar{h}_{jt}) = Pr(h_2(v_{jt}) > \bar{h}_{jt}) = Pr(v_{jt} < h_2^{-1}(\bar{h}_{jt})) = Pr(v_{jt} < \tilde{v}_{jt})$$
$$= \Phi(\bar{v}_{jt}), \text{or}$$
$$\bar{v}_{jt} = \Phi^{-1}(Pr(\tilde{i}_{jt} > \bar{h}_{jt} | \bar{h}_{jt}))$$

where $Pr(\tilde{i}_{jt} > \bar{h}_{jt} | \bar{h}_{jt})$ can be estimated either via kernel methods, or by approximating the cutoff value $\bar{v}(\bar{h}_{jt})$ by a flexible function of $\bar{h}_{jt}$ and carrying out a probit regression.

To estimate $h_2(v_{jt})$, we categorize all the uncensored observations (where $\tilde{i}_{jt} > \bar{h}_{jt}$) into distinct bins. Specifically, suppose the thresholds are $\{\bar{h}_1, \bar{h}_2, ... \bar{h}_{R+1}\}$. Then any uncensored observation $\tilde{i} \in (\bar{h}_r, \bar{h}_{r+1}]$ is placed in bin r. We carry out the BBL inversion separately for each bin. In particular, if $i^* = max(h_2(v^*), \bar{h}_{jt})$ for some arbitrary v^*, where i^* lies in bin r, then the following expression

must hold:

$$F(i^*|i^* \in (\bar{h}_r, \bar{h}_{r+1}]) = Pr(\tilde{i} \leq i^*|i^* \in (\bar{h}_r, \bar{h}_{r+1}))$$

$$= Pr(v \geq v^*|\bar{v}_{r+1} < v < \bar{v}_r)$$

$$= \frac{\Phi(\bar{v}_r) - \Phi(v^*)}{\Phi(\bar{v}_r) - \Phi(\bar{v}_{r+1})}$$

In other words,

$$i^* = F^{-1}\left(\frac{\Phi(\bar{v}_r) - \Phi(v^*)}{\Phi(\bar{v}_r) - \Phi(\bar{v}_{r+1})}\right) \text{ for } \bar{v}_{r+1} < v^* < \bar{v}_r$$

It is easy to verify that this estimator nests the uncensored example as a special case and allows us to better address censoring by increasing the number of bins. Monte Carlo simulations suggest that a small number of bins (say five) can lead to surprisingly well-behaved estimates with minimal bias in the estimated function $h_2(v)$.

A.4 First-stage Policy Functions and State Transition Estimates

This section presents the first-stage estimates of the investment and exit policy functions, as well as the state transition process. Table A2 reports the estimated investment policy function using OLS, Tobit, and CLAD. Table A3 reports the estimated exit policy function. Table A4 presents estimates of the transition process for the prices of bulkers, tankers, containerships, and steel.

A.5 State Space

As discussed in the main text, we approximate $V(s_{jt})$ via B-spline basis functions $V(s_{jt}) = \sum_{l=1}^{L} \gamma_l^0 u_l(s_{jt})$ and impose the Bellman equation as a constraint. Recovering γ^0 requires specifying the set of state values on which to evaluate the Bellman constraint. We construct a sample that ensures sufficient variation in each of the state variables. First, we include all the N states observed in the sample. Second, we randomly draw N_{add} additional states to span the full range of the state variables. The coefficients γ_0 are recovered using these $N + N_{add}$ states. This approach is similar to Sweeting (2013).

These additional states are instrumental in getting a good approximation of the value function, for two reasons. First, some states (for example, ship prices and the steel price) are highly correlated in the data, which makes it challenging to separately identify the coefficients on basis functions formed from these state variables if we only use the observed states. Second, some regions of the state space have a limited number of observations. Both of these problems can be mitigated by adding randomly drawn states, which avoids multicollinearity between states and ensures sufficient data points across all regions of the state space.

Table A2: Estimates of the investment policy function

	(1) OLS	(2) Tobit	(3) CLAD
Constant	-0.066	-12.2	-31.9***
	(7.54)	(8.17)	(4.09)
B-spline 1 Capital	-69.7***	-63.8***	-69.6***
	(22.0)	(17.2)	(1.67)
B-spline 2 Capital	-74.7***	-71.7***	-68.2***
	(17.7)	(13.5)	(1.41)
2006-08	6.42***	4.59**	17.9***
	(1.60)	(2.32)	(0.74)
2009+	2.70	3.79	3.55**
	(2.20)	(3.03)	(1.80)
$\bar{s}_{jt}$	0.74***	0.87***	1.44***
	(0.11)	(0.087)	(0.040)
Bulk price	2.05***	1.97***	1.34***
	(0.46)	(0.57)	(0.30)
Tanker price	0.48	1.89*	0.81***
	(0.93)	(1.14)	(0.13)
Container price	-1.25	-1.49	-0.55
	(0.87)	(1.06)	(0.34)
Steel price	-2.49***	-4.44***	-4.38***
	(0.53)	(0.61)	(0.19)
N	4286		
$N(I > 0$	3301		
$N(I = 0)$	985		

In Column (1), we carry out an OLS regression of investment (I) on basis functions of the states, including both observations with $I > 0$ and $I = 0$.

In (2), we estimate the policy function using a Tobit regression of I on the basis functions.

In (3), we estimate the investment policy function using a censored least absolute deviations estimator.

$\bar{s}_{jt}$ is an index capturing the effect of backlog, age, ownership, region, and size on a firm's per-period payoffs. Investment is measured in million RMBs in these regressions.

Table A3: Estimates of exit policy function

	(1)		(2)	
	Coefficient	SE	Coefficient	SE
Constant	-0.57	(0.97)	-0.56	(1.02)
K	0.05	(0.35)	0.54	(0.43)
K^2	-0.05	(0.12)	-0.16	(0.15)
2006-2008	-0.57	(0.41)	-0.64	(0.43)
2009+	-0.47	(0.41)	-0.72	(0.44)
$\bar{s}_{jt}$	-0.01	(0.01)	-0.04	(0.02)
Bulk price	0.36	(0.12)	0.36	(0.12)
Tanker price	-0.18	(0.11)	-0.16	(0.11)
Container price	-0.22	(0.10)	-0.25	(0.11)
Steel price	-0.06	(0.07)	-0.10	(0.08)
Jiangsu			0.77	(0.24)
Zhejiang			0.58	(0.19)
Liaoning			1.04	(0.28)
N(exit)	47		47	
N	4605		4605	
Residual deviance	478.59		459.47	
Log-likelihood	-239.30		-229.74	
Pseudo-R2	0.09		0.12	

We carry out a probit regression of a binary indicator of exit on basis functions of the states. We restrict the estimation to 1999-2011, because firm exits in 2012 and 2013 are not reliably measured.

	Bulk	Tanker	Container	Steel
Constant	0.88	0.70	1.25	-0.023
	(0.87)	(0.94)	(1.11)	(0.37)
Post	3.44	3.63	1.80	2.32
	(2.28)	(3.43)	(3.33)	(1.01)
Price (t-1)*Pre	0.86	0.92	0.88	0.89
	(0.12)	(0.086)	(0.090)	(0.19)
Price (t-1)*Post	0.86	0.86	0.88	0.69
	(0.072)	(0.095)	(0.10)	(0.11)
Trend*Pre	0.042	0.038	0.029	0.024
	(0.033)	(0.028)	(0.024)	(0.027)
Trend*Post	-0.058	-0.054	-0.040	-0.022
	(0.027)	(0.041)	(0.040)	(0.013)
N	57	57	57	57
R^2	0.95	0.97	0.96	0.80

[*] The dependent variable is the price in quarter t, or $p(t)$. Standard errors in parenthesis. "Pre" refers to 2005Q4 or earlier. "Post" refers to 2006Q1 or later. The sample ranges from 1999 Q4 to 2013Q4.

B Implementation of Counterfactual Analyses

Each of the counterfactual experiments involves two steps: first, solving for the new Bellman equation and policy functions, and second, simulating the industry forward until 2099. Here we briefly explain how to implement the first step through a fixed point algorithm:

1. Compute expected profits $\pi(s)$ at all states.

2. Start with an initial guess of the exit policy function $p^{0,x}(s)$ and investment policy function $i^0(s,v)$.

3. Update the policy functions. At each iteration j:

   - Solve for the value function coefficients γ^{j+1} using the equation $V^{j+1}(s) = \pi(s) + p^{j,x}\sigma + CV^{j+1}(s)$.

   - Update the investment policy function to $i^{j+1}(s,v)$ by solving the investment FOC, using V^{j+1} and CV^{j+1}. As the value function is approximated by cubic B-splines, the investment policy function has an analytic solution.

   - Update the exit policy function to $p^{j+1,x}$ using V^{j+1} and CV^{j+1}.

- Check whether $||p^{j+1,x}(s) - p^{j,x}(s)|| < tol$ and $||i^{j+1}(s,v) - i^j(s,v)|| < tol$, where *tol* is a pre-assigned tolerance level.

C A Simple Model on Subsidies

This is a static model with homogeneous firms. Each firm has a starting capital stock of K_0. Price is equal to P. Marginal cost of production equals $MC(q_t) = \alpha - \beta K + \delta q_t$. Total cost of investment equals $C_I(I) = c_1 I + (c_2/2)I^2$. The firm chooses q and I simultaneously to maximize profits:

$$V(K_0) = max_{q,I} Pq - \left((\alpha - \beta(K_0 + I))q - \frac{\delta}{2}q^2 \right) - \left(c_1 I + \frac{c_2}{2}I^2 \right)$$

The optimal quantity and investment are denoted by q^* and I^*, respectively.

Now suppose that the government introduces production subsidies of τ_p per unit. For simplicity, we assume that the firm only adjusts its level of production and not investment; thus investment remains fixed at I^*. The new level of production, $\hat{q}$, is:

$$\hat{q} = q^* + \frac{\tau_p}{\delta}$$

Alternatively suppose the government introduces investment subsidies of τ_i per unit. The new level of investment, $\hat{I}$, is:

$$\hat{I} = I^* + \frac{\tau_i}{c_2}$$

Below we provide expressions for the return to subsidies, which is the change in industry profits from the subsidies divided by the cost to the government of providing the subsidies, as well as the deadweight loss from subsidies:

$$\text{DWL from Prod. Subsidies} = \tau_p^2/2\delta$$
$$\text{DWL from Invest Subsidies} = \tau_i^2/2c_2$$
$$\text{Return to Prod. Subsidies} = (q^* + \frac{\tau_p}{2\delta})/(q^* + \frac{\tau_p}{\delta})$$
$$\text{Return to Invest Subsidies} = (I^* + \frac{\tau_i}{2c_2})/(I^* + \frac{\tau_i}{c_2})$$

Holding the adjustment cost parameters c_2 and δ fixed, the return to subsidies is increasing in I^* (for investment) and q^* (for production). In other words, subsidizing "better" firms leads to higher returns.

Our derivation of the DWL shows that the magnitude of DWL is independent of whether a firm has low or high marginal costs: τ_p^2/δ. Essentially, all firms (large or small) increase their output by

the same amount when they receive the same subsidy. However, the return to subsidies is higher for low-cost firms than high-cost ones. This is because low-cost firms receive a higher absolute amount of subsidies due to the fact that they produce a higher quantity. Thus the DWL loss is divided by a larger denominator which means the per-dollar return to subsidies is higher.