Industrial Policy: Lessons from Shipbuilding

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Abstract

Industrial policy has been used throughout history in some form or other by most countries. Yet, it remains one of the most contentious issues among policy makers and economists alike. In part, this is because the empirical evidence on whether and how it should be implemented remains slim. Scant data on government subsidies, conflicting theoretical arguments, and the need to account for governments' short and long-run objectives, render research particularly challenging. In this article, we outline a theory-based empirical methodology that relies on estimating an industry equilibrium model to measure hidden subsidies, assess their welfare consequences for the domestic and global economy, as well as evaluate the effectiveness of different policy designs. We illustrate this approach using the global shipbuilding industry as a prototypical example of an industry targeted by industrial policy, especially in periods of heavy industrialization. Just in the past century, Europe, followed by Japan, then South Korea, and more recently China, developed national shipbuilding programs to propel their firms to global leaders. Success has been mixed across programs, certainly by welfare metrics, even when not by growth metrics. We use our methodology on China to dissect the impact of such programs, what made them more or less successful, and how we can justify why governments have chosen shipbuilding as a target.

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1 Introduction

It has certainly felt like the topic of industrial policy woke up with a roar from a long quiet sleep. Since the Great Recession of 2008, governments around the world have been increasingly embracing industrial policy publicly. Interestingly, that is not limited to interventionist regimes like China, but includes the world's greatest proponents of free trade, such as the US and the EU. In fact, the truth is that throughout economic history most governments have been practicing industrial policy in one way or another.

Industrial policy refers to a government's intentional agenda to shape industry structure by either promoting or limiting certain industries or sectors. Despite its prevalence, our understanding of the implications of such measures is limited. Although casual observation tends to indicate that industrial policy can boost sectoral growth, we have not yet mastered evaluating its welfare impact, nor the efficacy of different types of government interventions. How do such policies impact the local and global economy in welfare terms? How do they affect international trade? How should industrial policy actually be done? Systematic and convincing empirical evidence that addresses these questions is disproportionally slim (see Lane [2020], for an excellent review of the existing empirical literature).

We are admittedly not surprised by this. In our decade-long research program, we have run into severe empirical and conceptual challenges.

First, government subsidies to industries are notoriously difficult to detect and measure. Indeed, partly because international trade agreements prohibit direct and in-kind subsidies, "systematic data are non-existent" (WTO, 2006) and thus the presence and magnitude of industrial subsidies is often unknown. This lack of both information and compliance has obstructed the role of global policy-makers such as the WTO, and prompted them to reevaluate their guidelines. Currently, discussions to reassess international directives are abundant.

Second, we need a methodology to assess the (welfare) impact of industrial policy domestically and globally. As we discuss below, the older literature has mostly followed one of two approaches: (i) explore descriptively the impact of gauged subsidy measures on outcomes such as (firm) output and productivity through regressions; (ii) rely on analytically tractable models to explore when industrial policy can be beneficial for the domestic economy. The first approach cannot inform us on welfare effects, while the latter proved too dependent on chosen specifications. The literature died down– until recently.

There are further methodological challenges. Measuring welfare effects necessitates the development of a modeling framework. But there are non-trivial choices to be made (e.g. partial vs. general equilibrium). Most important in our view, is the challenge of having to consider the government's objectives. When it comes to evaluating industrial policy, this difficult issue becomes first-order: for instance, how do researchers incorporate geopolitical considerations, abundant in industrial policy agendas today? Finally, the methodology should be informative about policy design; many argue that since industrial policy is stubbornly practiced, the real question is not *whether*, but *how* to actually do it.

In this article, we discuss our proposed methodology and the key take-aways from our research on one particular example of industrial policy, which we believe serves as a revealing case study: Chinese shipbuilding. Shipbuilding is often seen as a "strategic industry" and is thus one of the major recipients of subsidies globally, along with e.g. the steel, mining and automotive industries. As we describe below, it has been historically a classic target of industrial policy, pursued by several countries that devised national programs for heavy industrialization, such as Japan in the 1950's, and South Korea in the 1980's.

China is also naturally of great interest: it has had heaps of trade conflicts, in many industries and with many countries; while the lack of data is particularly acute (Haley and Haley, 2013). In the past two decades or so, Chinese firms have extremely rapidly dominated a number of capital intensive industries, such as steel, auto parts, solar panels and shipbuilding, see Figure 3. In recent years especially, the government is explicitly targeting sectors with the goal of turning its firms into world leaders (e.g. "Made in China 2025" plan). Government subsidies are often evoked as a possible contributing factor to China's expansion.

We outline how we tackled the challenge of poor data; our answer to the important question, "what-if" China had not subsidized shipbuilding: how would have the industry evolved in China itself, and its rival countries Japan and South Korea; and what about global consumers, and world trade. We also discuss a number of lessons for policymakers designing industrial policies, and finally, we ask why China may have subsidized shipbuilding.

2 Shipbuilding

Ships are the largest factory produced product. Over the centuries, ship design evolved dramatically: wood was replaced by steel in the 19th century, sails were replaced first by steam, and then by diesel-powered engines in the 19th and 20th centuries. In recent decades, progress has been less dramatic, yet we have witnessed the construction of larger and larger vessels, with further investments in engines and design. The major types of ships currently produced include containerships, (oil) tankers, bulk carriers, as well as more niche products like cruise ships, natural gas carriers (LNG's), car carriers, and Ro-Ro's.

Ship production requires land, access to water (sea or rivers), as well as materials such as steel and engines, and (skilled) labor. Labor constitutes at least 20% of costs, and inputs roughly 60% (Jiang and Strandenes, 2012). In addition, substantial capital investments are required. Even though cheap inputs (labor, material) determine a country's global competitiveness, a quick inspection of the history of shipbuilding reveals the decisive role that governments have played in shaping the landscape.

Indeed, throughout its century-long history, shipbuilding has been a target of government inter-

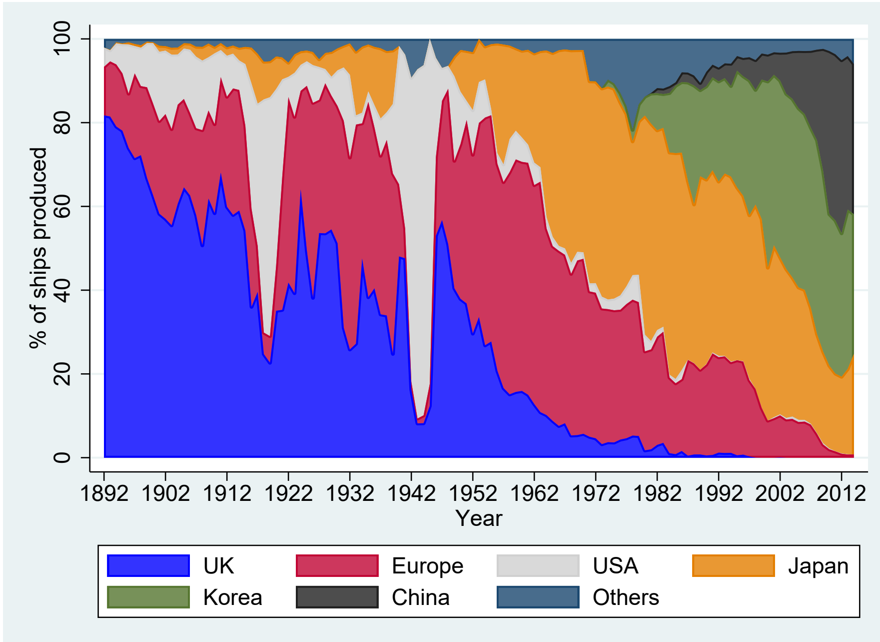

Figure 1: This figure plots the share of ships produced by each country, from 1892 - 2014. Data for 1892 - 1997 was obtained from historical issues of the World Fleet Statistics published by Lloyd's Register, while the data from 1998 onwards is based on Clarksons data.

ventions. This is because historically ships have been essential to a country's maritime trade, as well as its military capacities. Looking back at the modern history of shipbuilding, one is striken by the small number of countries that have dominated global ship production in sequence. As Figure 1 illustrates, the UK held the lion's share of the industry for the better part of the 19th and 20th centuries, slowly handing its place to Japan; until the 1980's when South Korea prevailed as the primary ship producer; before facing fierce competition from China in the mid-2000's.

The UK's leading position in shipbuilding, which lasted for decades and up until the 1950s, was in part due to its strong maritime trade: UK trade flows dominated global trade and the British Empire required ships to execute this trade volume with its colonies and other trading partners. In the same time period, other Western European countries with strong maritime traditions, such as Scandinavian countries, also enjoyed substantial market share in ship production.

During the two world wars, the US achieved striking production levels of ships: motivated by its military needs, massive shipbuilding capacity was built and later dismantled in a very short timespan. Beyond these two incidents, the US was never globally competitive as a ship producer. That said, an important lesson can already be learnt from this example: the speed at which a massive shipbuilding program can be set up is astonishing.

After World War II, in its efforts to rebuild its industrial base, Japan developed national programs for its shipbuilding industry, alongside several other heavy industries, such as steel, petrochemicals, and coal. An island nation, with a very strong maritime tradition, Japan swiftly became the world's dominant ship producer. Through a series of interventions, including subsidized financing, export credits and protectionist measures, a number of large Japanese conglomerates active in shipbuilding (as well as several other sectors) became global leaders. This includes household-name firms such as Mitsubishi, Kawasaki, and Sasebo. The program was so massive, that during the 1950's, 30% of the total loans made by the Japan Development Bank were for marine transportation (Stopford, 2009). By 1970, Japan's market share had increased to 48% (from only 4.7% in 1949), while Europe's market share had fallen from 75% to 48%.

By the 1980's Japan was losing ground to South Korea. Although there are important similarities between the ascent of South Korea and that of Japan, there are also important differences. South Korean shipbuilding, similarly to Japanese shipbuilding, grew as part of the government's large-scale push for heavy industrialization in the late 1970's (Lane, 2022, Choi and Levchenko, 2021). Recognizing shipbuilding as a strategic industry, the government provided support primarily in the form of favorable financing. Also like Japan, major South Korean conglomerates such as Hyundai, Samsung and Daweoo grew quickly and competed fiercely with their Japanese counterparts. Within 20 years, by 1995, South Korea's market share grew to 28% (from less than 1% in the early 1970s), reducing Japan's market share from 50% in 1975 to 41%, and Europe's share from 32% to 23%.

There was however a shift with South Korea's paradigm. Unlike all its predecessors, South Korea did not have a maritime tradition, or a large national fleet. Its maritime trade was much smaller than that of Europe, or Japan. Even as South Korea emerged as one of the two leading shipbuilding countries, its share of the global shipping fleet never exceeded 2%, whereas Japan's share had reached 10% by 1984 (Stopford, 2009).[1] In other words, this is the first time that shipbuilding is targeted as an exclusively exporting sector. In 1995, 78% of Korea's ships were exported, compared to 42% for Japan (Lloyd's, 1999). This shift can be partially attributed to the growing adoption of "flags of convenience": already from the late 1960's shipowners began choosing flags of countries that provided tax and licensing benefits, such as Panama or Liberia, instead of remaining loyal to their national fleet registry. This trend rendered shipowning a more "global" industry, breaking the link between shipowning and shipbuilding. Today, demand for ships remains globally fragmented and comes from many different countries and hundreds of different shipowning firms or fleet operators.[2]

So why did South Korea subsidize shipbuilding? Although the answer is unknown, it relies perhaps on the shipbuilding production process requiring skilled labor and sophisticated capital/machinery, its links to several sectors, and even just following the steps of nations that were previously successful in achieving heavy industrialization.

Finally, it is important to note that shipbuilding is an extremely volatile industry (see below, Panel

[1]This is likely a gross underestimate because of flags of convenience; for instance according to Stopford [2009] in 2005, 90% of Japanese-owned ships sailed under foreign flags.

[2]Industry structure for bulk carriers (tankers and dry bulk carriers) is highly fragmented with hundreds of firms operating globally (see Kalouptsidi, 2014). In container shipping, although operators are fairly concentrated, they often lease their vessels from a fragmented market of shipowners.

(d) of Figure 2). Kalouptsidi [2014] explains why shipping and shipbuilding cycles are notorious. Demand for ships is governed by large macroeconomic fluctuations. When demand spikes, but shipbuilding capacity is fixed and sluggish (building ships takes years), shipping rates skyrocket, shipowners enjoy high margins, and they pile up orders for new ships. Shipbuilding prices then soar. But in the bust, shipbuilding capacity idles because of fixed costs, and prices hit rock bottom.

By 2000, European shipbuilders focus on niche high-tech products, such as cruise ships. Their overall market share is 14%. Japan and South Korea compete head to head, with an overall market share of 38% each, but focus on different segments. Japanese yards dominate production of bulk carriers (with a share of 70%), while South Korean yards lead the production of higher-end, specialized oil tankers (61%) and containerships (50%). South Korea's shipbuilding industry (consisting of a small number of very large yards) also focuses on the production of larger ships. In the 2000's, China enters the scene.

3 A Model-Based Empirical Approach

The case of shipbuilding illustrates how carefully planned industrial programs can lead to quick and substantial sectoral growth. However, how can we evaluate the welfare impact of such growth, both domestically and internationally, as well as the efficacy of different types of government interventions? There are considerable challenges in answering these questions.

Challenges First, government subsidies to industries are notoriously difficult to detect and measure. Indeed, "systematic data are non-existent; reliable sources of information are scarce and mostly incomplete [...] because governments do not systematically provide the information" (WTO, 2006) and thus the presence and magnitude of industrial subsidies is often unknown. Therefore, researchers and policy makers have to rely mostly on self-reported data. This may include subsidies that are generally exempt from regulation, such as R&D, environmental and agricultural subsidies; or crude reported measures of output subsidies that tend to be untrustworthy. Even worse, it may even be the case that support measures are inherently unmeasurable: consider a government-built airport in a small city with a long runway (whose construction cost is enormous), is used by an aircraft manufacturer for large plane trials. How can we even quantify the size and impact of this effective subsidy?

Second, we need a methodology to assess the impact of industrial policy. This methodology must be useful for policy makers designing a policy mix, as well as international institutions that adjudicate subsidies disputes (i.e. (dis)prove "injury caused" by the alleged subsidies). In the former case, we must be able to compute welfare, while in the latter we are interested in the difficult question of "how would have this industry evolved absent the alleged subsidies?"

Prior research on industrial policy has taken two different approaches to address these challenges. The first relies on a largely descriptive analysis that regresses firm or sectoral outcomes on the measures of industrial policy that are available (e.g. Aghion et al. 2015, Harris et al. 2015, Juhász 2018, Choi and Levchenko 2021, Manelici and Pantea 2021, Lane 2022, Mitrunen 2023). This can be a very valuable exercise, especially in cases where data is relatively precise, and where appropriate instrumental variables (or sources of quasi-experimental variation) are available. We may learn the impact of industrial policy on important variables, including firm output, sales, profitability, growth, or productivity. However, this analysis only takes us part of the way. We cannot make welfare evaluations, or counterfactual predictions, such as gauge how industries would have evolved in the absence of subsidies, or even assess the differential impact of different policy instruments to inform policy design. This approach also tends to not be informative in terms of mechanisms through which industrial policy operates and affects the economy.

The second approach has been based entirely on theory. A significant body of work in international trade developed the theory of strategic trade, whereby government interventions alter the strategic interactions of firms that compete globally. The literature primarily focused on when industrial policies can be beneficial for the domestic economy and classified the outcomes of different combinations of market failures and types of interventions (e.g. Brander, 1995, Helpman and Krugman, 1989). The work was based on models that were simple enough to remain analytically tractable and deliver closed-form solutions; in a short follow-up literature, a few empirical studies calibrated such models (e.g. Baldwin and Krugman, 1988a,b, Head, 1994). Different specifications of the model, however, could entirely alter the conclusions drawn, thus not providing clear answers as to whether and how industrial policy should be employed. Because of this continual ambiguity, this literature died down relatively quickly, and remained dormant for decades, despite industrial policies being omnipresent in the world economy, posing the pressing question of whether and how they should be implemented.

Theory-based empirical work In the meantime, structural methodology in the field of Industrial Organization (IO) was making constant progress. This approach has the ability to address some of the challenges encountered in the study of industrial policy outlined above. It does so by essentially putting the two previous approaches together and harnessing the benefits of each. Unlike purely descriptive analysis, model-based empirical work looks at the data through the lens of an empirical industry equilibrium model, which allows for welfare calculations. And unlike the purely theoretical approach, it bypasses analytic tractability and closed-form solutions. It relies instead on devising the simplest model that is realistic enough to capture the main features of the environment under study, thus allowing for more accurate predictions.

So how does it work? The researcher builds a "custom" model for the industry under study (say shipbuilding). This requires a deep understanding of the environment: e.g., who are the producers and buyers, how do firms compete, how are prices formed, what is the production cost function, are there other important firm decisions, is the industry selling a homogeneous or differentiated good, how do government subsidies impact firms? Oftentimes, answers to these questions come from extensive discussions with industry participants, industry press or reviews, as well as potentially the prior academic literature. The model must account for all key features of the industry under study, and allow for the key mechanisms the researcher is interested in analyzing.

The model must then "meet" the data. The researcher collects data, usually in the form of firm actions, such as quantities produced, prices, investments, and product characteristics. Then, depending on the idiosyncrasies of the environment under study, one can develop or choose an existing technique from the field to estimate the model primitives of interest, most importantly, the demand curve, and the firm costs. This amounts to "assigning numbers" to key parameters of interest, such as the demand elasticity, and the marginal cost of production or investment.

Finally, this quantitative model is used to compute "counterfactuals" (i.e. hypothetical scenarios) of interest. This may include predicting the evolution of an industry absent subsidies (to do it, remove the subsidies from the model and re-compute the equilibrium, then compare to the observed). Or, it may involve performing a horserace between different types of industrial policies (to do it, change the policy mix in different ways and compare the new equilibrium to the observed). We illustrate this entire approach below, through the example of global shipbuilding.

There remains the question of how one measures subsidies. Our approach in the case of shipbuilding was the following: as we describe below, we knew that China began subsidizing in 2006. Thus, our strategy aims at uncovering a "gap" between the observed firm choices (for instance, production) and the choices the economic model would imply. To do so, we estimate the cost function of potentially subsidized firms, i.e. the function that relates output to operating expenditures, and examine its behavior around 2006. We are particularly interested in whether this cost function exhibits a "break" in 2006 in China, i.e. an abrupt change that makes Chinese shipyards produce as if their costs are all of a sudden lower.

Theory-based empirical work relying on IO techniques is not without its caveats in this context. The most important challenge we have faced is the big unknown that many economic models shy away from: the government's objectives. When it comes to evaluating industrial policy, this issue becomes important and difficult to handle: for instance, how do researchers incorporate geopolitical considerations, prevalent in industrial policy agendas today? Moreover, there is a choice to be made between partial and general equilibrium. Partial equilibrium or sector-specific analysis (as in IO) allows us to exploit rich data and institutional details to answer important "what-ifs". However, there are interesting aspects of general equilibrium analysis that can be used to explore sectoral spillovers of the policy (see for instance Liu [2019] who shows such spillovers can be key in justifying and implementing industrial policy). Finding ways forward combining benefits from different approaches seems to us a fruitful research objective.

4 Illustration: China's Recent Shipbuilding Program

Chinese Industrial Policy in Shipbuilding At the turn of the century, China's nascent shipbuilding industry accounted for less than 10% of world production. In 2002, former Premier Zhu inspected the China State Shipbuilding Corporation (CSSC), one of the two largest shipbuilding conglomerates in China, and pointed out that "China hopes to become the world's largest shipbuilding country (in terms of output) [...] by 2015." Soon after, the central government issued the 2003 National Marine Economic Development Plan and proposed constructing three shipbuilding bases centered at the Bohai Sea area (Liaoning, Shandong, and Hebei), the East Sea area (Shanghai, Jiangsu, and Zhejiang), and the South Sea area (Guangdong).

The most important initiative was China's 11th National 5-year Economic Plan 2006-2010, which was the first to appoint shipbuilding as a "strategic industry" in need of "special oversight and support"; the central government "unveiled an official shipbuilding blueprint to guide the medium and long-term development of the industry". As part of the national plan, the central government set specific output and capacity goals: annual production was to reach 15 million deadweight tons (DWT) by 2010 and 22 million DWT by 2015. Remarkably, both goals were met several years in advance. Indeed, within just a few years, China overtook Japan and South Korea to become the world's leading ship producer in terms of output, as shown in Panel (a) of Figure 2. By 2009, China's market share had reached 53%, from less than 10% in 2000; the combined market share of Japan and South Korea decreased from 75% in 2000 to 42% in 2009.

During the time period under study, which spans 2001 to 2014, a famous shipbuilding cycle took place. In the early 2000's China's international imports (mostly commodities) and exports (mostly manufacturing) boomed, commodity prices soared, and as a result shipping rates spiked to a historical high. Shipowners placed heaps of new ship orders and shipyard backlogs grew exponentially; by the end of 2008, the global ship backlog was more than 5 times larger than in 2001. But the boom was stopped short by the Great Recession of 2008. The crisis led to an idling of the existing fleet, at the same time that another 70 percent of that fleet was still scheduled for delivery by 2012. Shipbuilding prices plummeted and threatened the survival of many shipyards.

Let us now provide more details on China's policy mix. China's national and local governments provided numerous types of subsidies, which we classify in three groups. First, below-market-rate land prices along the coastal regions, in combination with simplified licensing procedures, acted as "entry subsidies" that incentivized the creation of new shipyards. As as shown in Panel (b) of Figure 2, between 2006 and 2008 China exceeded 30 new shipyards *per year*; in comparison, during those same years, Japan and South Korea averaged only about 1 new shipyard per year each. In the booming mid-2000s, many of the orders were placed in these Chinese "greenfields", which were taking orders as they were getting built themselves.

Second, regional governments set up dedicated banks to provide shipyards with favorable financ-

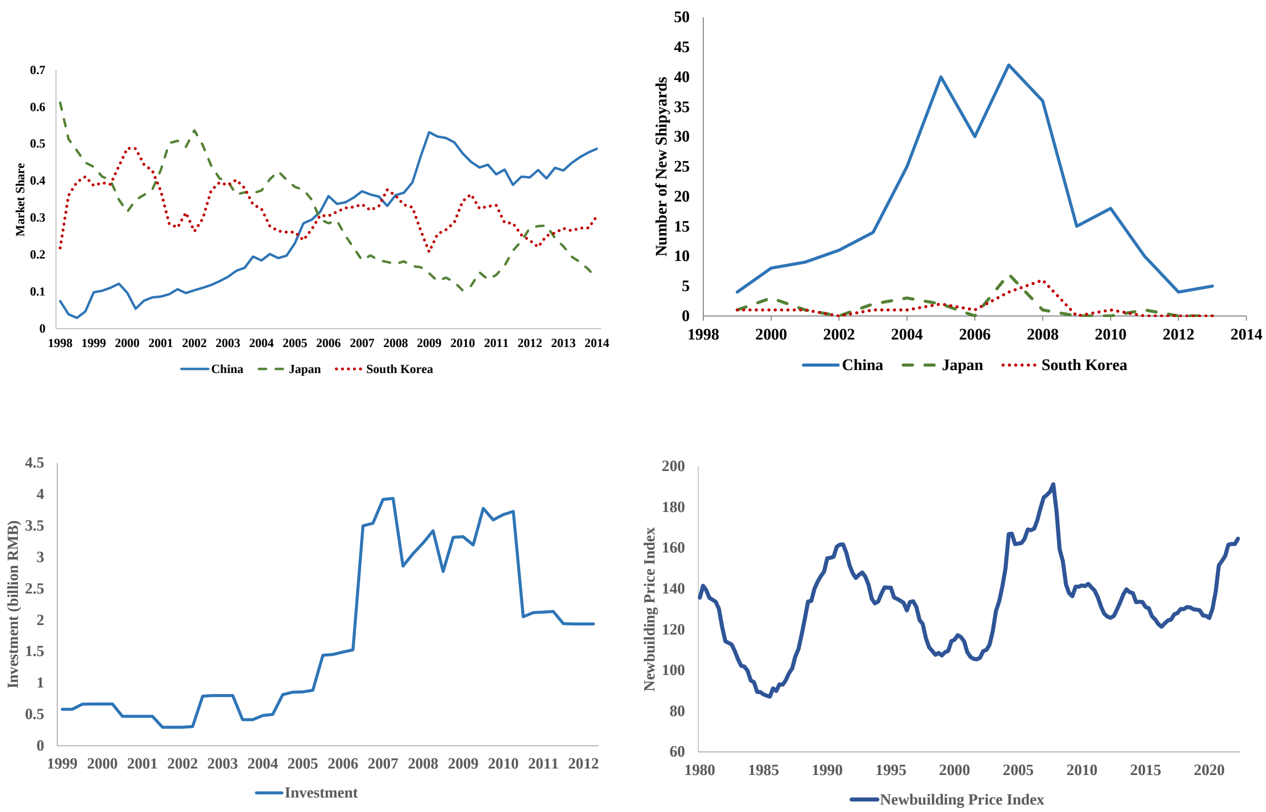

Figure 2: Figures (a) - (c) illustrate the rapid expansion of China's shipbuilding industry. (a) Source: Clarkson Research. Market shares by country are computed from quarterly ship orders. (b) Source: Clarkson Research. Number of new shipyards annually and by country. (c) Source: China's National Bureau of Statistics. Industry aggregate quarterly investment by Chinese shipyards in billions of 2000 RMB. (d) Source: Clarksons Research. Quarterly newbuilding price index (=100 in January 1988).

ing terms. These "investment subsidies", in the form of low-interest long-term loans (a common industrial policy tool, as illustrated also by the programs of Japan and South Korea) and preferential tax policies allowed for steep capital accumulation in the 2000's. This is illustrated in Panel (c) of Figure 2.

Finally, the government also employed "production subsidies" of various forms, such as subsidized material inputs, export credits, and buyer financing. The government-buttressed domestic steel industry provided cheap steel, which is an important input for shipbuilding. Export credits and buyer financing by government-directed banks made Chinese shipyards more attractive to global buyers: at those times when Chinese shipyards were young and unfamiliar, receiving a favorable loan to purchase from them proved an effective incentive.

The combination of these policies led to unprecedented expansion in China's production, market share, capital accumulation, as well as to a proliferation in the number of Chinese firms (Figure 2). China's market share grew from 14% in 2003 to 53% by 2009, while Japan shrunk from 32% to 10% and South Korea from 42% to 32%. This impressive output growth was partially achieved via a massive entry wave of new firms: there were 173 new Chinese firms, a 230% increase in 5 years. It is worth noting that most of China's output growth was then concentrated in the least high-tech products (50% global share in bulk carriers) vs. oil tankers or containerships (28% and 23% respectively), where it concentrated also on smaller sizes.

By all accounts it seemed like shipbuilding was getting yet another global leader; but then, the Great Recession drove the industry to a historic bust in 2008. The large number of Chinese shipyards exacerbated low capacity utilization and plummeting ship prices. The effectiveness of China's industrial policy was deeply questioned. In response to the crisis and in an effort to promote industry consolidation, the government unveiled the "2009 Plan on Adjusting and Revitalizing the Shipbuilding Industry" that resulted in an immediate moratorium on entry and shifted support towards only selected firms in an issued "White List". Concentration in the industry started increasing.

And what has happened since the period of our analysis, which ended in 2013? China continues to be the world's leading shipbuilder, accounting for 54% of all ships delivered in 2022, compared to 28% for South Korea and 18% for Japan. Moreover, evidence suggests that China has begun to slowly move up the product ladder: between 2018 and 2022, Chinese shipbuilders delivered 45% of all new containerships (versus 36% for Korea), up from 23% between 2006 and 2010; albeit, they still build the smaller containerships. They have began building bigger ships, in the simpler ship types, such as bulk carriers.

It is worth noting, that these patterns are by no means unique when it comes to China's industrial policy. Several industries saw this rapid expansion of output growth and firm entry, accompanied by excess capacity during busts, as well as regional industrial duplication; see Figure 3. In sectors such as solar panels, auto manufacturing and steel, several Chinese regions also developed their own (fragmented) industry inhabited by a large number of small firms. This is in sharp contrast to the policies

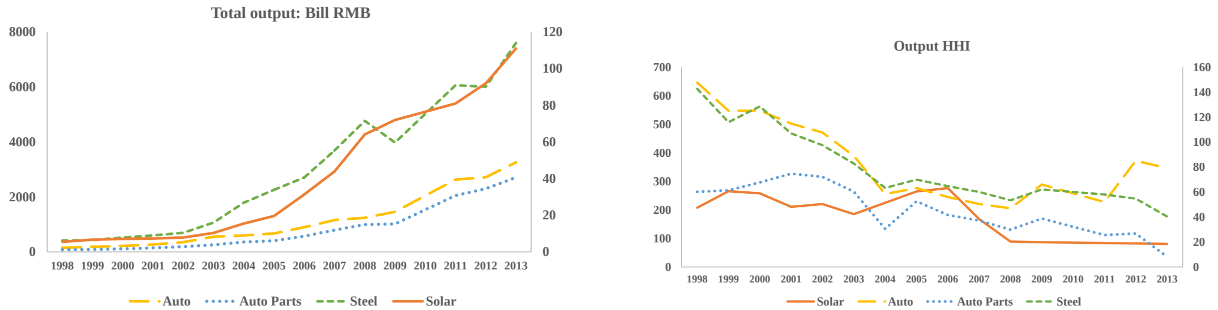

Figure 3: These figures illustrate that several industries in China have followed similar patterns to shipbuilding. Source: China's National Bureau of Statistics. On the left figure, the output of the auto, auto parts, and steel industries are plotted on the left vertical axis, while the output of the solar industry is plotted on the right vertical axis. On the right figure, the HHI of the auto and solar industries are plotted on the left vertical axis, while the HHI of the auto parts and steel industries are plotted on the right vertical axis.

adopted by Japan and South Korea, which relied on promoting a handful of large conglomerates that became global industry leaders.

Our methodology In recent work, we rely on the model-based empirical strategy of IO outlined above to assess the consequences of industrial policy on industry evolution and global welfare (Kalouptsidi, 2014, Barwick et al., 2023). Since measuring subsidies is a prerequisite for this analysis, we first provide a methodology to detect their presence and gauge their magnitude. The main object of interest of this methodology is to recover the "true" costs of potentially subsidized firms. We then quantify the impact of subsidies on the economy.

How does one gain insight on the governmental support offered to firms, when the measures applied are unknown? We rely on structural Industrial Organization estimation techniques that combine available data on firm choices and an economic model to detect the presence of subsidies. In particular, our approach aims at uncovering a "gap" between the observed firm choices (consider production, as one example) and the choices the economic model would imply. To do so, we estimate the shipbuilding cost function, i.e. the function that relates output to operating expenditures, of potentially subsidized firms. As in many industries, however, costs of production are not readily observed. Our strategy amounts to estimating costs from changes in demand, and examining its behavior around 2006. We are particularly interested in whether this cost function exhibits a "break" in China in 2006, i.e. an abrupt, and otherwise inexplicable change that makes Chinese shipyards produce as if their costs are all of a sudden lower.

More specifically, the simplest version of the economic model can be described as follows. There is a global market for ships, and a large number of shipowners across the world decide whether to buy a new vessel. Depending on the market conditions, notably world trade and the current fleet level, shipowners have a certain willingness-to-pay for a new ship. When world trade grows and the total number of ships is low, shipowners have a high willingness-to-pay and invest in new vessels. The more vessels they buy, the more the fleet grows and their willingness-to-pay declines, all else equal.

We consider shipyards located in China, Japan, South Korea and Europe. Each shipyard decides how many ships to build, by comparing the ship market price, dictated by the shipowners' willingness-to-pay, and its production costs. The shipyard will keep producing, as long as the price exceeds the cost of the additional vessel. For instance, suppose we see a shipyard producing three vessels during a quarter; this must mean that the shipyard's profitability was higher for three vessels rather than either two or four. This implication of optimal behavior lets us use the observed ship prices and quarterly firm chosen production to bound, and in the end uncover the shipyard's cost function.

Let us illustrate how we estimate production subsidies in this toy model.

Example. Suppose the demand curve for ships is given by $P_t = A_t - bQ_t$, where P_t is the price of a new ship in time period t (t may be a quarter or a year), Q_t is the total number of ships produced in t, A_t captures the "size of the market" in period t and may be governed by macroeconomic fluctuations, while b is a parameter determining the price elasticity for ships. Suppose that shipyards are price-takers in the market for ships and choose how many ships to produce in each period, subject to the convex cost function, $c_{jt}(q_{jt}) = c_1 q_{jt} + c_2 q_{jt}^2$, for shipyard j in period t, where the convexity may capture capacity constraints. Shipyard j then solves

$$\max_{q_{jt}} P_t q_{jt} - \left(c_1 q_{jt} + c_2 q_{jt}^2\right)$$

This implies that the optimal quantity produced is $q_{jt} = (P_t - c_1)/2c_2$, and the global ship price is $P_t = A_t - bNq_{jt} = (2c_2 A - bc_1 N)/(2c_2 - bN)$, where N is the number of shipyards.

When production subsidies are introduced for some shipyards in 2006, the cost function becomes, $c_{jt}(q_{jt}) = (c_1 - s)\, q_{jt} + c_2 q_{jt}^2$, where s is the per unit subsidy. Shipyards are now facing lower per unit costs, and their optimal production is higher than before. It is now equal to $q_{jt} = (P_t - c_1 + s)/2c_2$; equilibrium prices fall due to the higher total production.

By comparing observed firm level production before and after 2006 (as well as for Chinese and non-Chinese shipyards, which would have been captured by two different types of firms in this toy model), we can estimate the level of s. Here is the intuition: use data before 2006 to estimate the cost function, i.e. the parameters c_1, c_2 from the optimal production level; then, use the post-2006 level and the known cost parameters to back out s.[3] In other words, our model delivers the optimal firm-level production in the absence of subsidies. A deviation from the optimal production post-2006 informs us on what the subsidy s must have been. The idea is to essentially ask whether Chinese firms are "over"-producing, compared to our theoretical prediction. With the model in hand, we can then evaluate the welfare effects of industrial policy, by comparing the observed outcome with the outcome that would

[3]Note that in the expression $q_{jt} = (P_t - c_1)/2c_2$, we observe q_{jt} for all j,t, as well as the price P_t. Hence we can essentially run the regression, $q_{jt} = \beta_0 + \beta_1 P_t + \varepsilon_{jt}$, where $\beta_0 = 1/2c_2$ and $\beta_1 = -c_1/2c_2$. From these we can uncover β_0, β_1.

have arisen had China not subsidized shipbuilding.

There are of course two caveats with what we have said so far: (i) this model is too stylized; (ii) we must rule out other confounding factors. We discuss them both.

The actual model employed is more flexible in several dimensions, in order to capture a world that is substantially more complex. Both shipping (demand side) and shipbuilding (supply side) are at the mercy of large macroeconomic swings, and firms operate in the shadows of severe uncertainty regarding both demand for international trade, as well as input cost shocks (e.g. steel prices). Moreover, in both shipping and shipbuilding firm expectations are important. On the demand side, ships are long-lived investments for shipowners, and so their demand depends on expectations about future growth and fleet development. On the supply side, ship production takes time: building a ship takes two to five years and thus shipyards accumulate backlogs, which can affect their future production costs, either negatively (capacity constraints), or positively (expertise acquisition). The economic model employed can account for these factors.

In addition, as described earlier, the government also provided investment and entry subsidies, which led to substantial shipyard entry and capital accumulation. We explore the impact of these subsidies as well, by modeling the dynamic behavior of firms to account for entry and investment.

In the end, we employ a dynamic model of industry evolution, where firms can enter, exit, invest to increase their capital, and compete by producing ships. Demand for new ships is driven by demand for international sea transport, which is uncertain and volatile. Shipyards decide to enter by comparing their lifetime expected profitability to entry costs. They exit if their expected profitability from remaining in the industry falls below a given threshold, capturing the shipyard's "scrap" value (i.e., the costs or proceeds from liquidating the business, as well as any opportunity costs or option values of the firm). And their optimal production amounts to comparing current margins to expected costs, given input price fluctuations and backlog accumulation. Subsidies along all three margins (production, entry and investment) are estimated by comparing Chinese to non-Chinese firms, before and after 2006. Accounting for dynamics proves to be first-order: the impact of industrial policy is long-run and thus affects the long-run behavior of firms. Thus thinking about decisions such as entry, exit and capacity investment, which all take into account an uncertain future, matters in evaluating the effectiveness of industrial policy.

We employ a rich dataset consisting of firm-level quarterly ship production between 1998 and 2014, firm-level investment, entry and exit and new ship market prices by ship type (containerships, tankers, and dry bulk carriers, accounting for 90% of all sales).

Our findings: how big were the subsidies? 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 compared to the size of the industry. Our estimates suggest that $91 billion were handed over between 2006 and 2013, averaging over $11 billion per year; this totaled nearly 50% of Chinese industry revenue over that period. This finding is driven by the cost function obtained from this analysis, which exhibits a significant drop for Chinese producers equal to about 13-20% of the cost per ship. Similarly, entry costs exhibit a 51-64% decline in 2006 (depending on the province), which led to considerable firm entry. In addition, the subsidies were disproportionately in the form of entry subsidies (69%). Production subsidies were 25%, and investment subsidies accounted for only 6%.

The intuition for the estimated cost decline is simple: it is practically impossible to explain the rapid increase in China's market share that was observed, with other economic mechanisms consistent with this model and our knowledge of the empirical setup. Simply put, Chinese firms are "over"-producing, compared to our theoretical prediction. Similarly, they "over-entered"– recall the astonishing entry rates during the boom years of 2006-2008, as shown in Panel (b) of Figure 2– and "over-invested" – recall the striking increase in investment *during the bust*, post the Great Recession, as shown in Panel (c) of Figure 2.

Let us now address the caveat of confounding factors. We provide evidence that a number of possible alternative explanations for the recovered cost decline cannot adequately account for the observed patterns. The drop in costs is only present for Chinese shipyards– there are no "breaks" in the cost functions of Japanese, South Korean or European yards. This suggests that the Chinese cost decline is not due to some sudden global technological change. In addition, the results are robust to many different specifications for the cost function, as well as different ways of accounting for other temporal changes. We find particularly convincing that the results hold when only shipyards that existed prior to 2001 are considered. This suggests that cost declines are not driven by new shipyards, which may have a different technology or may be learning by doing. Finally, the results hold if we focus on the smallest size category of bulk vessels (called Handysize), as (i) China was already an important producer before 2006; (ii) their production process is not characterized by significant technological advances; (iii) product differentiation is very limited.

Our findings: welfare impact and design of industrial policy We now harness the biggest advantage of having a quantitative model for this industry: we use it to perform hypothetical scenarios. We first ask what would have happened absent Chinese subsidies? Presumably, China's market share would still have increased some, especially during the boom years; but by how much? Then, we dissect elements of industrial policy design; for many, the "how" of industrial policy is much more pertinent than the "whether", given how ubiquitous it is already (Rodrik, 2010).

The policy boosted China's domestic investment and entry by 140% and 120%, respectively, and increased its world market share by over 40%, thus leading to substantial reallocation of global production. Government support more than doubled the entry rate: 143 firms entered with subsidies vs. 64 without subsidies from 2006 to 2013. It also depressed exit.

Chinese subsidies reduced South Korea's world market share from 48% to 39% and Japan's market share from 23% to 20% during 2006-2013, with profits earned by shipyards in these two countries falling by RMB 144 billion. Importantly, 70% of this expansion occurred via business stealing from rival countries. There is also evidence that Chinese shipyards are less efficient than their Japanese and South Korean counterparts; thus, the business stealing that occurred constitutes a misallocation of global resources.

The industrial policy led to considerable declines in ship prices. Lower ship prices benefited world shipowners somewhat, though only a modest amount accrues to Chinese shipowners, as they accounted for a small fraction of the world fleet.

Although the subsidies were highly effective at achieving output growth and market share expansion, we find that they were largely unsuccessful in terms of welfare measures. The program generated modest gains in domestic producers' profit and worldwide consumer surplus. In the long run, the gross return rate of the adopted policy mix, as measured by the lifetime profit gains of domestic firms divided by total subsidies, is only 18%.

Given this disappointing return, we use our model to understand why this was the case, as well as how different policy designs may have yielded better results. We first examine each policy in isolation to understand the economic mechanisms that each type of subsidy activates. Interestingly, the effectiveness of different policy instruments differs greatly. Production and investment subsidies can be justified if the goal is revenue maximization (the rate of return as measured by the ratio of increased industry revenue to subsidies is 153%). This might explain the popularity of these subsidies in China, since quantity and revenue targets are often linked to local officials' promotions.

Entry subsidies however are wasteful even by the revenue metric and lead to increased industry fragmentation and idleness. This is because entry subsidies attract small and inefficient firms; the firms that take up entry subsidies likely would not have entered without them. This implies these are low productivity firms. In contrast, production and investment subsidies increase the backlog and capital stock, which both lead to economies of scale, and drive down both current and future production costs. As such, they favor large and efficient firms that benefit from economies of scale. Indeed, the take-up rate for production and investment subsidies is much higher among firms that are more efficient: 82% of production subsidies and 68% of investment subsidies is allocated to firms that are more efficient than the median firm, whereas only 49% of entry subsidies goes to more efficient firms.

Thus, the low return of the industrial program was to some extent due to the policy design, which by relying on entry subsidies, attracted a large number of inefficient producers and exacerbated the extent of excess capacity. This was painfully revealed during the Great Recession. But we also learn, that the government objectives matter when thinking about policy effectiveness, an issue we return to below.

Entry subsidies were particularly ineffective because of the volatile nature of the industry, which is subject to boom and bust cycles. When should the policy maker subsidize? We use the model to explore this, by considering subsidies at different times of the cycle. A counter-cyclical policy would outperform the pro-cyclical policy that was adopted by a large margin: strikingly, subsidizing firms during the boom leads to a net return of only 38%, whereas subsidizing firms during the downturn leads to a much higher return of 70%. There are two main contributing factors to this finding: convex production and investment costs, and firm composition. In boom periods, the industry is operating close to full capacity. Further expansion is costly and entails the utilization of high-cost resources. Firms that are already producing and investing may choose to engage in more rapid expansion than is optimal, incurring large adjustment costs. During a bust, on the other hand, the industry operates well below capacity and many production facilities remain idle. Subsidies mobilize underutilized facilities, resulting in smaller distortions. The second contributing factor is the changing firm composition over the business cycle. Subsidies during a boom attract inefficient firms, which pushes down the rate of return. Despite the benefits of a counter-cyclical policy, the actual policy mix was overwhelmingly pro-cyclical: 90% of total subsidies was handed out between 2006 and 2008 vs. 10% between 2009 and 2013.

Finally, we examine the consolidation policy adopted in the aftermath of the financial crisis, whereby the government implemented a moratorium on entry and issued a "White List" of firms that are prioritized for government support. This strategy was adopted in several industries to curb excess capacity and create national champions that can compete globally, following the examples of Japan and South Korea.

We find that directing subsidies towards specific firms can generate considerable gains. If the "optimal White List" is formed (i.e. the most productive firms are chosen), the net rate of return is 71% vs. 37% when all firms are subsidized. Why? Subsidizing all firms encourages suboptimal entry, while the White List policy, by subsidizing existing firms does not distort entry. Moreover, firms on the White List have lower production costs; shifting support to more efficient firms reduces misallocation. Although targeting low-cost firms significantly reduces distortions, the government's actual White List was suboptimal, as it favored state-owned enterprises (SOEs). This illustrates a further difficulty with designing industrial policy: regulatory capture.

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

Industrial Policy in Shipbuilding: Why? If industrial policy was as ineffective, why did China do it? Answering this question has been an important challenge in our research agenda. What are the objectives that a government is trying to attain via industrial policy? To what extent are policies based on "economics", as opposed to other geopolitical considerations? Here is what we have uncovered for the case of Chinese shipbuilding.

In this setup, we have struggled to find support for many of the typical rationales for industrial policy that economists have put forth. Strategic trade considerations are largely irrelevant because the shipbuilding industry is fragmented globally and market power is limited. In other words, since markups are slim, there are no 'rents on the table' that, when shifted from foreign to domestic firms, outweigh the cost of subsidies. Moreover, there is no evidence of industry-wide learning-by-doing (Marshallian externalities), another common rationale for industrial policy. Similarly we find limited evidence for significant spillovers generated by shipbuilding to other domestic sectors (e.g., steel production or the labor market), that would justify the amount of subsidies we uncover. Moreover, more than 80% of ships are exported, which limits the fraction of subsidy benefits that is captured domestically. Dynamic considerations, whereby Chinese output growth eventually forces competitors to exit, does not seem first-order either: by 2023, no substantial foreign exit has been observed.

We do however find support for two different rationales. First, a rationale that might justify China's shipbuilding subsidies relates to the role of ships in international trade: a larger worldwide fleet reduces transportation costs. As China became the world's biggest exporter and a close second largest importer in our sample period, transport cost reductions can lead to substantial increases in its trade volume. China's imports consist mainly of raw materials and are carried by bulk carriers and tankers; while its exports are mostly manufactured goods and are transported in containerships. To evaluate this argument, we carry out a back-of-the-envelope calculation of the subsidies' impact on China's trade flows. Subsidies reduced bulk carrier freight rates by 6% and containership freight rates by 2% between 2006 and 2013. Using trade elasticities from the literature (Brancaccio et al., 2020, Jeon, 2022), the industrial policy raised China's annual trade volume by 5% ($144 bn) between 2006 and 2013. This increase in trade was certainly large relative to the size of the subsidies (which averaged $11.3 bn annually between 2006 and 2013). Of course, "more trade" does not necessarily translate into higher or lower economic wellbeing; but figuring out the welfare gains from trade would require additional modeling of general equilibrium effects.

Second, there is evidence that military ship production might have benefited from China's industrial policy. Military ship production is concentrated at state-owned yards with substantial commercial ship production. It takes place at thirteen subsidiaries of China State Shipbuilding Corporation (CSSC) and China Shipbuilding Industry Corporation (CSIC), the two largest conglomerate shipyards that are also state-owned.[4] These subsidiaries are typically dual-use, producing both commercial and

[4]Our primary sources are the yearly report known as IHS Jane's Fighting Ships, produced by the intelligence company IHS Jane's Saunders [2015] , as well as "Chinese Naval Shipbuilding: an Ambitious and Uncertain Course", a 2017 book

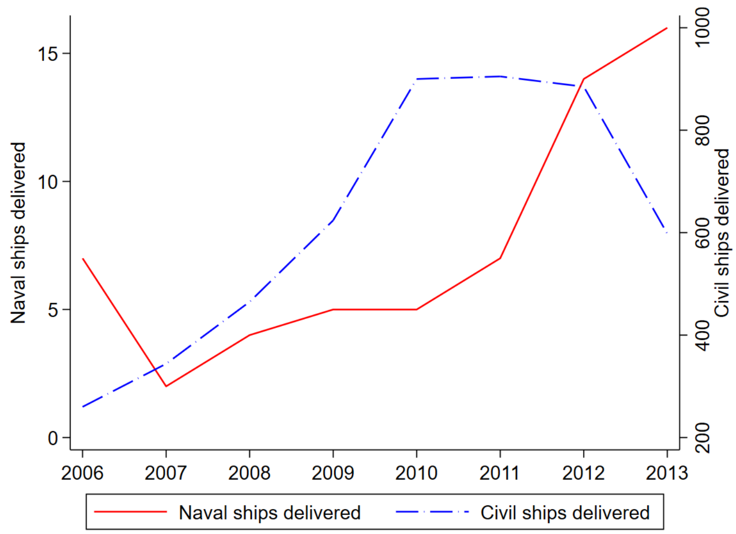

Figure 4: Military Ship Production. This figure plots the number of commercial ships and naval ships delivered by Chinese shipyards over time. Source: Clarksons and IHS Jane's.

military ships in the same complex. Figure 4 plots the annual deliveries of naval and commercial ships from 2006 to 2013. As depicted, both types of deliveries experienced a several-fold increase during this period, although military production appears to have accelerated after the financial crisis and continued to increase throughout the sample period, providing suggestive evidence that China's supportive policy might have benefited its military production as well.

5 Conclusion

The example of Chinese shipbuilding, which echoes patterns observed in other countries and industries, clearly illustrates many of the academic and policy-making challenges of industrial policy. It showcases the issue of scant and mismeasured data on government interventions. This lack of data hinders international trade agreements and prevents researchers and policy makers from evaluating policies. It also highlights the complexity of designing industrial policies: China started with large subsidies (such as cheap land and subsidized credit) without many restrictions on the firms that could access them. This proved costly and inefficient as it led to a massive entry wave of new firms that were not the high performers. This poor design was hidden during the boom years, but brutally revealed when in the Great Recession idleness and excess capacity plagued the industry. The government stepped in to "pick the winners" and subsidize only firms on a White List; this pattern seems to continue today in the "Made in China 2025" program. Interestingly, very recently shipbuilding has entered industrial policy agendas in both the EU (Folkman, 2024) and the US (Forooher, 2024),

about the Chinese naval shipbuilding industry Erickson [2017]. We are grateful to Elliott Mokski for discovering and collecting these datasets.

with calls for re-shoring shipbuilding production. Finally, our case study poses the question of why governments engage in these policies. Understanding this requires us to think outside the standard toolbox of a modern economist and poses a great challenge but also opportunity for economic research. The literature on industrial policy is already growing fast; we believe the combination of different techniques and methodological approaches will be crucial in making progress in informing economic policy.

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