The Persistent Effect of Temporary Input Cost Advantages in Shipbuilding, 1850-1911 *

W. Walker Hanlon
NYU Stern School of Business & NBER

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Abstract

Can temporary input cost advantages have a long-run impact on production patterns? I study this question in the context of shipbuilding from 1850-1911. While North America was the dominant wood shipbuilding region in the mid-19th century, the introduction of metal shipbuilding shifted the industry to Britain, where metal inputs were less expensive. After 1890, Britain's input price advantages largely disappeared but its dominant position in the industry persisted. I show that American shipbuilders exposed to British competition struggled to transition to metal shipbuilding and present evidence that the mechanism behind Britain's persistent lead was the development of pools of skilled workers.

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Author contact: NYU Stern School of Business, 44 West 4th St. Room 7-160, New York, NY 10012, whanlon@stern.nyu.edu.

1 Introduction

Can initial input cost advantages have a persistent influence on patterns of trade and production, even after those advantages disappear? This is a classic question in international trade, with implications for our understanding of the origins of current trade patterns as well as the impact of certain forms of industrial policy. The answer to this question is particularly relevant today, given ongoing debates over the use of government intervention to protect domestic industries.

An ideal empirical setting for studying these issues would be characterized by a set of similar locations, some of which enjoy an initial input cost advantage that eventually disappears, such that all locations face similar cost and demand conditions in the long-run. Identifying settings fitting this description has proven difficult. As a result, our understanding of the extent to which temporary advantages can have long-run effects on trade patterns remains extremely limited, particularly given the importance of the issues at stake, which are central to current trade policy debates.

This paper studies the international shipbuilding industry from 1850 until just before the First World War, a setting that provides the features needed in order to look at the long-run effects of temporary input cost advantages.[1] In the mid-19th century, North American shipbuilders were the dominant producers in this industry. However, Britain had a more advanced iron industry in the mid-19th century which resulted in lower iron input prices. This initial input cost advantage, together with the rise of metal shipbuilding after 1850, allowed British shipyards to attain a dominant position in the industry by 1880. However, during the 1880s and 1890s Britain's initial input costs advantage largely disappeared due to the discovery of new iron reserves in North America and the development of successful American iron and steel producers.

The main analysis in this study thus focuses on the decade after 1900, when initial differences has essentially disappeared and locations in Britain and Eastern North America faced similar cost and demand conditions. I show that, despite losing their advantage in

[1] I end the study period just before the First World War to avoid the massive disruption in the shipbuilding industry caused by this conflict.

metal input costs, British producers maintained a dominant position in the shipbuilding industry after 1900, while North American shipbuilders, despite their earlier dominance in the industry, struggled to adapt the new metal shipbuilding technology. This pattern is particularly striking given the broad success of American manufacturing in general, and metal goods manufacturing in particular, during this period.

The goal, then, is to understand the role that Britain's temporary initial advantage played in this process, and specifically, why the dominant position that British shipyards established by 1880 persisted after Britain's initial cost advantages had disappeared. To make progress here, I take a somewhat novel approach. Rather than focusing on British shipyards and trying to understand why they were successful, I instead turn the question around and ask: why were North American producers largely unable to catch up to the British after 1890, despite having similar raw materials costs as well as a long history of shipbuilding?

Focusing on North American producers is useful because it allows me to take advantage of two novel sources of variation in exposure to British competition. Studying the effect of exposure to British competition can reveal whether Britain's initial advantage persisted in part because British competition retarded the development of the industry in other locations. Having exogenous variation in exposure to this competition is necessary in order to rule out the possibility that North American producers failed to successfully transition to metal shipbuilding because of other factors.

The first source of variation in exposure to British competition that I exploit is generated by the fact that shipbuilders in the Great Lakes were protected from foreign competition because of the difficulty of moving large ships through the locks and canals connecting the Lakes with the Atlantic. This geographic barrier created a market that remained largely isolated from foreign competition until the construction of the St. Lawrence Seaway in the 1950s. Other than selling into separate output markets, I show that shipbuilders did not face systematic differences in input costs or demand conditions on the Great Lakes relative to the Atlantic Coast. I also exploit a second source of exogenous variation in exposure to foreign competition driven by access to government protection. In particular, while the U.S. used a range of protective policies to aid domestic shipbuilders, Canada was unable to offer similar protections to domestic producers because it was part of the British Empire.

These sources of variation allow me to develop a counterfactual for the development of North American shipbuilding in the absence of competition from initially advantaged British producers. Comparing this counterfactual to the development of the industry in Atlantic Canada, which was fully exposed to British competition, identifies the impact of exposure to initially advantaged British producers on the development of the North American industry. Moreover, focusing the analysis on a comparison between wood and metal shipbuilding helps me to deal with a variety of factors, such as unskilled wage levels, access to finance, or the availability of shipyard space, that affected both types of shipbuilding.

To track the development of the shipbuilding industry in each location, I draw on detailed new data covering ship output by location from 1850-1911. These unique data are available because in order to obtain insurance ships need to be inspected and listed on a register, such as Lloyd's Register. These registers provide a catalog of the majority of large merchant ships constructed during the study period, including information on their size, construction material, location and year of construction, etc. The register data used in this paper were digitized from two sources, Lloyd's and the American Bureau of Shipping. The data come from thousands of pages of raw documents and cover tens of thousands of individual ships, providing a fairly comprehensive view of the development of the shipbuilding industry in North American and Britain.

My main findings show that North American shipbuilders that were protected from British competition, either because they were in the Great Lakes or the protected U.S. Coastal market, rapidly adopted metal ship production once the cost of metal inputs in North America converged to British levels. In contrast, in those areas fully exposed to British competition, such as the Canadian coast, the industry failed to make the transition and was effectively eliminated as an important industrial sector. These results indicate that British shipyards remained more productive than the North American yards that competed with them, even after their initial input cost advantages had disappeared, and that the failure of North American producers to successfully transition to metal shipbuilding can be linked directly to exposure to competition from more productive British yards.

This evidence raises questions about the specific mechanisms through which Britain's initial advantage was translated into persistently higher productivity. In the second half of the paper I try to shed light on these mechanisms. A natural starting point for thinking about how a temporary initial cost advantage might have had long-lasting effects is the presence of learning-by-doing. In fact, previous work by Thompson (2001) has already documented the presence of important dynamic learning in shipyards. However, the learning documented by that study occurred *within* shipyards.[2] This type of learning is unlikely to explain the persistent advantage of British producers because individual shipyards remained small relative to industry output and concentration in ship production was never high. A more likely explanation is that, in addition to within-firm learning, there were also localized learning spillovers. Such external learning spillovers could explain the persistent dominance of British shipbuilding firms as well as why these firms were spatially concentrated in the areas around Glasgow, Newcastle-upon-Tyne, Sunderland and Belfast. However, direct empirical evidence is needed in order to verify that external learning effects were in fact a feature of the shipbuilding industry.

In order to provide evidence that this industry was characterized by localized learning effects, I exploit the locations of Navy Shipyards in the U.S. These shipyards were established around 1800, long before the introduction of metal ship production, so their locations were unlikely to have been chosen to advantage metal shipbuilding. When the U.S. Navy began large-scale metal ship construction in the 1880s, these shipyards began producing and repairing metal ships. Thus, the Navy Yard locations provide plausibly exogenous variation in local experience in metal ship production. Using this, I study whether this experience had benefits for nearby private shipbuilding firms, consistent with localized learning effects.

Indeed, my analysis shows that private shipyards located near Navy shipyards were much more likely to make the transition from wood to metal ship production. These effects disappear for locations more than 50km from Navy yards. This result continues to hold when controlling for other ways that firms might have benefited from proximity to Navy yards,

[2]Thornton & Thompson (2001) looks at learning occurring across shipyards, but it is important to note that those shipyards are typically not located near to one another. Thus, that study may miss learning effects that are localized, exactly the sort that I find evidence for.

such as winning government contracts. Thus, I conclude that the shipbuilding industry was characterized by dynamic localized learning effects. The presence of these dynamic effects can explain why Britain's initial advantage resulted in a persistent lead.

In the last part of the paper I consider the specific nature of the localized learning effects I have documented. In principal these could take a variety of forms, including direct knowledge spillovers, specialized input producers, or the development of pools of local workers with specialized skills. An extensive review of contemporary sources and historical studies of the shipbuilding industry leads me to conclude that the most important factor translating initial input cost advantages into persistent trade patterns was likely the development of large pools of skilled craft workers. Metal shipbuilding required a variety of skills which were acquired through experience. These skills were crucial, and differed in important ways from the skills needed in either wood shipbuilding or other metalworking industries. Contemporary reports describe how Britain's initial advantage in metal shipbuilding led to the development of pools of skilled workers that substantially improved the productivity of British yards. Because these skills were embodied in a large number of workers, and because production required a wide variety of skills, coordination problems made the relocation of shipyards difficult, locking in a source of local advantage. North American shipbuilders lacked easy access to these pools of skilled workers, resulting in higher wages and costs. While they compensated by substituting toward unskilled labor and capital, the high cost of skilled work that could not be eliminated left them less productive than their British competitors. While this evidence is historical, rather than statistical, and should be evaluated as such, it offers a compelling and coherent explanation for why initial input cost advantages allowed British shipbuilders to gain, and then maintain, a dominant position in the industry in the decades before the First World War, as well as why these advantages remained localized.

The role of temporary initial advantages in influencing long-run trade patterns and welfare outcomes is the subject of a substantial theoretical literature in international trade (e.g., (Krugman, 1987; Lucas, 1988, 1993; Grossman & Helpman, 1991; Young, 1991; Matsuyama, 1992)). However, generating empirical evidence in this area has proven to be challenging. This study contributes to a limited set of empirical research in this area, including Krueger & Tuncer (1982), Baldwin & Krugman (1988), Head (1994), Irwin (2000), Juhasz (2018), Lane (2016) and Mitrunen (2019), as well as work on persistence in urban economies such as Bleakley & Lin (2012). Among this set, the most related recent paper is Juhasz (2018), which exploits the Napoleonic blockade to show that temporary protection from foreign competition in output markets can have persistent effects. An important difference in my study, relative to previous work, is that I focus on the impact of temporary input cost advantages, rather than output market protection. This is an important distinction, particularly given that input subsidies have been one of the main tools used in some prominent industrial policy cases, such as in Korea (Lane, 2016).

One difference between this study and previous work such as Juhasz (2018) is that I attempt to delve deeper into the underlying mechanisms behind the persistent effects that I document. While external learning is thought to be important for both the rate of growth and the spatial distribution of economic activity, it is often difficult to study empirically. This study provides new statistical evidence of learning effects as well as historical evidence indicating that the likely source of these effects is the development of pools of skilled local workers, a channel often overlooked in existing work.

The importance of skilled workers helps explain a number of features of the shipbuilding industry. For example, the role of experience in generating worker skills provides a potential explanation for the dynamic learning effects documented in existing studies (Searle, 1945; Rapping, 1965; Argote *et al.*, 1990; Thompson, 2001).[3] The existence of locked-in sector-specific skills can also help explain the continuance of wood shipbuilding in Eastern North America long after the technology was clearly inferior to metal and wood supplies had dwindled (Harley, 1970, 1973). Finally, the importance of skilled worker pools can also help explain the geographic concentration of the industry despite the relatively small size of individual firms.

[3]These papers have been primarily focused on estimating the magnitude of learning effects rather than identifying the mechanisms that drive them. Thornton & Thompson (2001) extend this analysis to a variety of ship types during the WWII period.

2 Empirical setting

The shipbuilding industry was an important industrial sector in the British, U.S. and Canadian economies in the 19th century.[4] This industry underwent dramatic changes during the period covered by this study, including the shift from wood ships to vessels made of iron or, later, of steel. In the 1850s, iron shipbuilding was still in its infancy. By the last decade of this study, iron and steel shipbuilding had come to dominate and metal ships accounted for 96.4% of the tonnage produced in the U.K., U.S. and Canada. However, in the U.S. and Canada wood shipbuilding remained important, accounting for 17.5% of the tonnage produced from 1901-1910.

The transition from wood to iron and steel was driven by two main factors. One was the shift from sail to steam power.[5] The share of steamships in total production rose from near zero before 1850, passed 50% of production after 1880, and made up over 95% of production in 1900-1910 (see Appendix A.4). This advantaged metal ships, which were better able to handle the increased vibration and hull stress associated with steam power (Harley, 1973). One implication of this fact is that, while wood and metal ships were highly substitutable for many purposes, they were not perfect substitutes.[6]

The second key factor driving the shift to metal hulls was improvement in the quality and reduction in the price of iron and steel inputs, together with the increasing scarcity of timber resources near the main shipbuilding locations. At the beginning of the study period there was a distinct pattern of input cost advantages in the shipbuilding industry that determined production patterns (Pollard & Robertson, 1979). In particular, the forests of the Eastern U.S. and Canada gave North American shipbuilders cheap access to wood. As a result, the U.S. was the world's leading shipbuilder, while Canada was also an important ship producer. Not only were the North American producers larger, they were also more innovative, introducing new designs such as the clipper. However, shipbuilders in Britain had access to

[4]In Britain, Pollard & Robertson (1979) estimate that aggregate wages in shipbuilding made up roughly 1-2 percent of total British wages from employment in the period from 1871-1911 (p. 36). The importance of the industry in the U.S. is harder to estimate, but likely to be similar.

[5]The shift from sail to steam was due in large part to improvements in engine efficiency (Pascali, 2017).

[6]Another dimension in which these were not perfect substitutes had to do with ship size. As shown in Appendix A.6, the largest ships could only be built of metal.

cheaper iron inputs thanks to their large domestic iron industry, giving British producers an early lead in iron shipbuilding. These advantages were important; while quantitative estimates of the share of costs accounted for by metal or wood inputs are scarce, and would have depended substantially on the specifics of any given design as well as fluctuating input prices, historical sources make it clear that the price of these inputs played a major part in determining overall costs.[7] For example, evidence from *Report of the Merchant Marine Commission* to Congress (1905) indicates that, in 1900, the cost of metal inputs accounted for between one-quarter and one-third of the price of a standard 5,000-ton freighter.

By the late 19th century, however, these initial input price differences had almost completely disappeared. This is shown in Figure 1. For wood prices, shown in the top panel of Figure 1, the rise in (eastern) U.S. prices was due to the increasing scarcity of forests near the shipbuilding areas (Hutchins, 1948). As a result, by the late 19th century, shipbuilders on the Atlantic coast of North American often had to import wood from the Great Lakes region (Hutchins, 1948). For iron prices, shown in the middle panel of Figure 1, the convergence between North American and British prices was driven by the discovery of new iron ore reserves in the U.S., such as the rich reserves in the Mesabi iron ore range in Minnesota.[8] These discoveries led to an expansion in U.S. iron and steel production and drove a surge in manufacturing exports starting in the 1890s (Irwin, 2003).[9] While Figure 1 describes iron prices, similar patterns appear for steel.[10] U.S. iron and steel exports surged from $25.5 million (3% of exports) in 1890 to $121.9 million (9% of exports) in 1900 and reached $304.6

[7]See, e.g., Culliton (1948) or Pollard & Robertson (1979).

[8]I focus on pig iron prices here and in later discussions despite the fact that this would have to go through several other production steps before being used by shipbuilders. One reason is that pig iron was more standardized than products further down the production chain, so prices are easier to compare across locations. A second reason is that pig iron was a key input into more specialized products used by shipbuilders. A third important reason is that products made from pig iron were used in a wide set of industries, so production is less likely to be endogenously affected by the local shipbuilding than products more specialized for use in ships.

[9]In addition to providing a ready supply of ore, the chemical composition of Mesabi ore improved productivity (Allen, 1977, 1979).

[10]Allen (1981) reports that, "Before the 1890s American [steel] prices substantially exceeded British prices, and the American industry achieved a large size only because of high tariffs. During the 1890s American prices dropped to British levels or below, and America emerged as a major exporter of iron and steel." Focusing on steel rails in particular, Allen found that, "Between 1881 and 1890 the average price of steel rails at Pennsylvania mills was $37.01 while the average British price was $23.62. During the period 1906-13 the American price had fallen to $28.00 while the British price had risen to $29.46."

million (12.5% of exports) in 1913 (Irwin, 2003). By 1900, U.S. manufacturers were even exporting substantial amounts of iron and steel to Britain.[11]

In Canada, the development of local coal mining and iron and steel production had similar effects. This occurred both in the Great Lakes and along the Atlantic Coast. Of the Canadian Atlantic Coast, an area that is particularly important for this study, Sager & Panting (1990, p. 15) write that, "It is difficult to show that the Atlantic region as a whole lacked the resources necessary to make the transition to iron steamships, and all the more difficult when Nova Scotia acquired an iron and steel complex. The region possessed coal, iron ore, capital, a labor 'surplus,' and long experience in ship construction and management." Supporting this, appendix A.7 shows that Canadian iron and wood price trends were similar to U.S. prices.

The dramatic reduction in transport costs that occurred in the second half of the 19th century, together with changes in tariff policy, also contributed to input price convergence, by giving coastal North American shipyards easier access to foreign suppliers.[12] As a result of this combination of factors, the strong initial patterns of comparative advantage driven by input prices that defined the shipbuilding industry in the mid-19th century had essentially disappeared by 1900, as shown in the bottom panel of Figure 1.

One feature of shipbuilding during the period I study was the highly competitive and fragmented nature of the industry. Hutchins (1948), for example, describes shipbuilding as "naturally one of the most highly competitive of all markets..." The main reason for this diffuse market structure appears to be geographic constraints that limited the size of individual shipyards, particularly the older yards located in larger towns. Competition in the industry was also increased by the very low cost of transporting a ship between navigable locations (relative to the cost of production). This meant that shipyards had to compete directly even with very distant competitors in a global market.

[11] It is worth noting that U.S. steel producers with market power in the U.S. may have been dumping steel in Britain in some years.

[12] Jacks & Pendakur (2010) and Jacks *et al.* (2008) provide evidence that international trade costs fell substantially during this period. For shipbuilding, the Dingley Tariff of 1897 helped reduce the cost of inputs by specifically exempting from duty steel used in the construction of vessels for the foreign trade (Dunmore, 1907). This gave shipbuilders the option to buy from European steelmakers and increased the foreign competition faced by U.S. steel producers, particularly on the coast.

The Great Lakes represented an important exception to the global ship market. In particular, prior to the opening of the St. Lawrence Seaway in the 1950s it was difficult for large vessels to transit between the Great Lakes and the Atlantic Ocean. This geographic barrier created an effectively isolated Great Lakes market. As evidence of this, my data show that in 1912, 97% of the vessels (by tonnage) homeported on the Great Lakes were also constructed on the Great Lakes, while over 94% of the tonnage constructed on the lakes remained there.[13] In terms of size, in the decade from 1901-1910 the Great Lakes market accounted for 2.3 million tons of production or 12.5% of total tonnage produced in the U.K., U.S. and Canada.

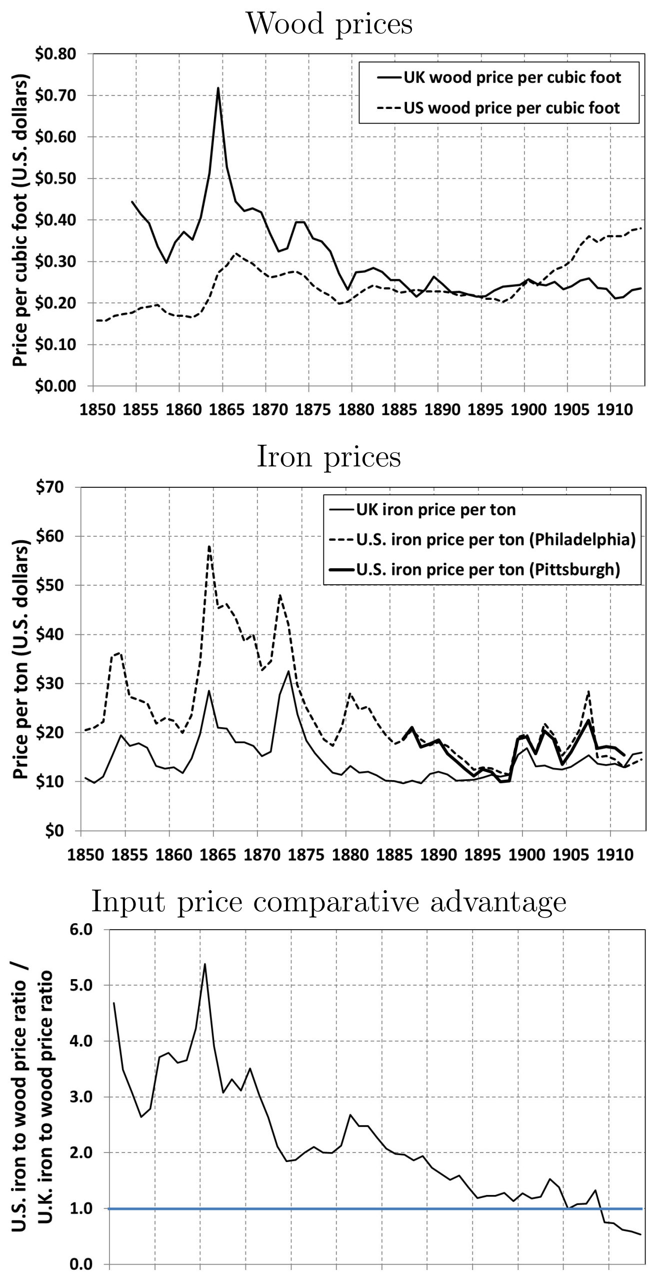
The main reason for this isolation was the limitation placed on the size of vessels that could pass through the canals connecting the Great Lakes to the Atlantic, particularly the Welland Canal, which bypassed Niagara Falls to connect Lake Erie and Lake Ontario, and the Lachine Canal on the St. Lawrence River at Montreal. To pass these canals, large vessels had to be cut apart and then later reconstructed. This was a time-consuming and costly process.[14] The *Annual Report to the Commissioners of the Navy* (1901, p. 15) states that, as a result, "Construction on the seaboard and on the lakes up to the present time should be considered as different industries, indirectly related."

Though protected from foreign competition, the other factors driving the transition from

[13]In contrast, only 82% of the vessels (by tonnage) homeported on the Atlantic Coast of the U.S. and Canada in 1912 were also constructed there and only 83.5% of the tonnage constructed on the Atlantic Coast between 1890 and 1912 remained there in 1912. Of course, this understates the openness of the coast market because the coastal ports of North American were also served by a large number of vessels homeported in other countries that operated on international routes, while Great Lakes ports were served only by vessels homeported on the Lakes. In Appendix A.12 I review additional evidence comparing the openness of the Great Lakes and Atlantic ship markets.

[14]Thompson (1991) writes (p. 45), "The larger foreign-built ships, those too long to negotiate the locks in the Welland or St. Lawrence...had their midbodies removed, and the remaining bow and stern sections were welded together. With the midbody sections stowed in their cargo holds, the downsized ships made their way through the locks...Once above the Welland, the vessels would again be cut in half and the midbody sections reinstalled before the ships were put into service." The *Annual Report to the Commissioners of the Navy* (p. 15) says of this method, "The experiment of building large vessels, cutting them in two to pass the locks, and then reuniting the parts has been made successfully in a few instances, but at the present time it does not appear that this method...will become general." There are also reports of ships that moved into the Great Lakes by going up the Mississippi river and through the Illinois and Michigan Canal, but this required that the ships have their entire superstructure removed in order to pass under the river bridges along the route. In addition, there were small metal vessels called *canallers* because they were built to be able to pass through the small St. Lawrence and Welland Canals. Some of these made their way into the Great Lakes in the 1890s, but these smaller ships were usually under 250 ft long.

Figure 1: Input prices and relative prices in the U.S. and U.K., 1850-1913



Notes: U.K. iron prices are from the Abstract of British Historical Statistics. U.K. wood prices are from the Statistical Abstract of the United Kingdom. U.S. prices are from Historical Statistics of the United States, Colonial Times to 1870, Vol. 1. U.K. prices are converted into dollars using the exchange rates reported by `http://www.measuringworth.com/exchangeglobal/`.

wood to metal in the Great Lakes market were similar to conditions on the Atlantic Coast. For example, the data presented in Table 1 show that there were no systematic differences between iron and wood prices on the Great Lakes compared to the Atlantic Coast. While iron prices were relatively low in some Lakes states, like Illinois, they were high in others, such as Michigan and Ohio. Similarly, there is no evidence that Atlantic coast producers had a relative advantage in wood prices.[15]

On the demand side, incentives for producing metal rather than wood ships in the Lakes were also similar to on the coast. This is important because one of the identifying assumptions in the main analysis is that there were no factors that systematically increased the demand for metal ships *relative* to wood ships (I do not need to assume that trends in overall demand for shipping capacity were similar across locations). For example, the transition from sail to steamships that took place in the Lakes was similar to the transition in the Atlantic market as a whole, as described in Appendix A.4. The incentives for using metal provided by opportunities to construct larger ships were actually weaker in the Great Lakes than on the Coast, because, as shown in Appendix A.6, maximum ship sizes in the Lakes remained smaller than in the Atlantic.[16] On the other hand, metal ships did last longer on the Lakes because freshwater was less corrosive, which may have provided some increased incentive for metal ship production there. While ships on the Lakes did have different designs than those on the coast, such as being longer and skinnier to maximize use of the available locks, there doesn't seem to have been any important differences in the techniques used to construct lake ships.[17]

[15] The 1900 Census, the source of these data, mentions that the very low price observed for Illinois is likely to be understated because in that location most pig iron was used internally by firms to produce steel.

[16] The smaller size of ships on the Great Lakes was due to the limitations imposed by locks and canals, particularly the lock between Lake Superior and the lower Great Lakes.

[17] One sign of the similarity of techniques used on the Lakes and the Coast is provided by the *Annual Report of the Commissioners of the Navy* from 1901, which suggests that coastal shipbuilders may be able to learn from the more successful yards on the Great Lakes (p. 15): "...through the training of shipbuilders, the invention and improvement of shipbuilding tools, machinery, and materials, and through experience gained in the financial and industrial organization of shipyards, the establishments on the Great Lakes are promoting the chance for seaboard growth."

Table 1: Iron and wood prices in some Atlantic and Great Lakes States, 1900

Region	State	Pig iron price in 1900	Lumber price index in 1900	Iron/lumber price ratio
Atlantic	New Jersey	16.81	14.23	1.18
	Maryland	12.69	8.65	1.47
	Virginia	15.20	7.64	1.99
Both				
	New York	15.07	10.95	1.38
	Pennsylvania	14.98	10.58	1.42
Great Lakes				
	Ohio	15.75	11.59	1.36
	Michigan	16.46	10.07	1.63
	Illinois	10.23	9.03	1.13
	Wisconsin	13.34	7.51	1.78

Notes: Data are from the U.S. Census for 1900. See description in Appendix A.9.

One may wonder if ships on the lakes were more constrained by depth limitations in a way that increased the attractiveness of building with metal. I examine this possibility in Appendix A.13 using data on the drafts of 1,000 ships collected from the 1912 ABS registry. These data provide no evidence that Great Lakes ships were built using designs that reduced depth, which suggests that depth limitations did not impose a substantially different constraint on the lakes than on the coast. Of course, this is setting aside the impact of depth on the Welland and Lachine Canals connecting the Lakes to the Atlantic, where depth limitations and other size constraints essentially precluded the passage of large vessels. Large ships constructed on the lakes were never intended to pass through these.

It is also natural to wonder whether the structure of ship ownership was different in the Great Lakes than on the Atlantic Coast. An examination of this issue, in Appendix A.14, shows that the concentration of ownership was low in all locations and fairly similar for ships homeported on the Atlantic Coast (HHI=503) and the Great Lakes (HHI=700). Thus, variation in ownership concentration in different areas is unlikely to be an important factor in the analysis.

This study takes advantage of a second form of exogenous variation in protection from foreign competition generated by access to government protection. Specifically, I take advantage of the fact that the U.S. actively protected domestic shipbuilders while Canada could not offer similar protection.[18] Support from the U.S. government came in two forms. First, the U.S. imposed a ban on the use of foreign-built ships for direct trade between American ports (coastal trade). This policy, which existed throughout the study period and continues today, created a protected market for U.S. shipbuilders. Essentially, this policy acts like a prohibitively high tariff on the import of ships for use in the coastal trade. The size of this market in 1901-1910 was equal to about 8.7% of the total tonnage produced in the U.S., U.K. and Canada during this period.[19]

A second important channel of government influence on shipbuilding was through the Navy. Warship construction gave domestic shipyards experience and may have helped generate pools of skilled workers.[20] From 1901-1910 the U.S. Navy bought vessels totaling 643,441 tons. While Navy vessels sizes are measured in displacement tons, which is not directly comparable to the tonnage measure for merchant vessels, this is roughly equivalent to 3.3% of total U.S., U.K. and Canadian tonnage.

While the U.S. had access to the full range of protective policies, Canada, as part of the British Empire, did not have the ability to enact similar policies. Specifically, Canada could not close coastal trade to British-built ships, nor did it have an independent navy during this period to provide orders to domestic yards or to operate government shipyards.[21] As

[18] It is worth noting that Britain also had some policies that benefited British shipbuilders during this period, despite the country's general *laissez-faire* economic philosophy. Among these was Naval shipbuilding as well as support for fast mail steamers. While these policies certainly aided British shipbuilders to some extent, as I discuss at the end of Section 4 the key margin of competition between British and North American shipbuilders was in sales to third-party buyers, a market segment that would not have been directly impacted by these British policies.

[19] This estimate is based on the size of U.S. coastal production. Given that only U.S.-built ships could be used in the U.S. coastal trade, and given evidence suggesting that U.S. shipbuilders were largely unsuccessful in selling ships outside of that market, I use the size of U.S. coastal production as a measure of the size of the U.S. coastal market.

[20] Hutchins (1948) suggests that the substantial expansion of the U.S. Navy in the late 1880s and 1890s, often described as the "New Navy" because the new ships were metal rather than wood, played an important role in the development of U.S. shipbuilding. Appendix A.10 describes the increases in U.S. Navy shipbuilding during the study period. Another type of industrial policy was the subsidization of passenger liners on mail-carrying routes which had to be served with domestically-built ships. This form of protection was particularly important during the inter-war period.

[21] Canada's status as part of the British Dominion made enacting protection against the mother country "scarcely thinkable" (Sager & Panting, 1990, p. 171). While Canada did impose tariffs on some British goods, ships were different from other products for a number of reasons. Among these was the fact that Canadian ships were protected by British maritime power, since Canada did not possess its own Navy until

a result, data for 1912 show that 46% of the total tonnage homeported in Canada in that year was constructed in the U.K. In contrast, only 7.6% of the tonnage homeported along the U.S. coast was built in the U.K. Thus, comparing the experience of the U.S. and Canada allows us to observe the evolution of this industry with and without access to government protection.

While my analysis takes advantage of output market segmentation at the regional level (U.S. Great Lakes, U.S. Coast, Canada Great Lakes, Canada Coast), within these regions there was enormous heterogeneity across locations. The length of the Great Lakes stretches over 1000km West to East, from Minnesota to New York State, and over 700km from North to South, with over 7,000 km of coastline. Shipbuilding took place in large cities such as Chicago, Toronto and Detroit, but also in many small out-of-the-way locations, such as Thunder Bay, ON and Saugatuck, MI. Coastal shipbuilding in Canada spanned a distance of over 1,600 km, from Montreal to St. John's, Newfoundland. On the U.S. Coast, shipbuilding locations stretched over 2,000km from Maine to Florida. As a result, even within a region, individual shipyards faced variation in input prices, availability and quality of shipyard space, labor market conditions, etc. This is reflected in the wide variation in state-level input prices *within* regions shown in Table 1, despite the fact that I do not observe systematic differences in input prices *across* the regions. This variation motivates my use of individual locations as the unit of analysis. The one factor that tied together the heterogeneous set of shipyard locations within each region was segmentation in the output market, the key source of variation exploited in this study.

the Royal Canadian Navy was founded in 1910 (and initially it was equipped with surplus Royal Navy vessels). Canadian shipping companies were also dependent on access to British ports as well as access to international ports granted through treaty agreements between the British Empire and other nations allowing the free entry of ships, which Canada was bound by. These geopolitical concerns made it practically impossible for Canada to protect shipbuilders from British competition. Practical difficulties also made it hard to exclude British vessels. Sager & Panting (1990) explain that because Canada used the British registration system for vessels, it was "virtually impossible to distinguish between British and Canadian ships, and hence a customs duty on British ships [in the Canadian foreign trade] would be impossible to enforce." Finally, the relatively weak political position of the Maritime Provinces in the Canadian Confederation also limited support for shipbuilders.

3 Data

The main analysis relies on a unique new data set derived from individual ship listings on two registers, one produced by Lloyd's and the other by the American Bureau of Shipping (ABS, sometimes called "American Lloyd's"). The primary purpose of these registers was to provide insurers and merchants with a rating of the quality of each ship. This provided shipowners with a strong incentive to have their ship included on at least one major register, and often more than one. As a result, the registration societies claimed that the vast majority of major merchant ships (e.g., over 100 tons) were included on one of the lists.[22] The data cover only merchant ships; warships are not included in the analysis. The vast majority of these were cargo carriers, though the data also include passenger liners, some fishing and whaling vessels, and other miscellaneous types (tugs, large barges, etc.).

The registers were published annually and included a variety of information about each ship. Appendix Figure 8 provides an example of the data from the first page of the Lloyd's Register for 1871-72. From each register, I have digitized the ship name, type (sail vs. steam), construction material (wood vs. metal), tonnage, the location and year of construction, and in some cases the shipyard and current home port.[23]

This study uses data from registers for three years, 1871, 1889 and 1912.[24] Because the registers include all active ships in these years, and because ships generally last many years after construction, these snapshots provide coverage for most ships built between 1850 and 1911.[25] Specifically, I use the 1871 register to track ships built before 1871, the 1889 register to track ships built between 1871 and 1887, and the 1912 register to track ships from 1888-1911.[26] For each snapshot year I digitized both the Lloyd's Register and the ABS Register.

[22]To be included on a register, a ship had to be inspected. This often occurred multiple times during the construction process and at periodic intervals after construction was complete. To complete these inspections, the registration societies employed a set of local inspectors in the majors shipbuilding areas of the world.

[23]The register also included additional information about the current owner, home port and master of each ship. These data were not entered for cost reasons. The home port of each ship was entered for the 1912 ABS Register only.

[24]The use of these snapshots is driven primarily by cost concerns. Digitizing each register requires entering data from thousands of pages of documents by hand, so even with outsourcing this to low-cost providers the cost is substantial.

[25]The patterns over time described in my data are similar to those found in available aggregate statistics (see Appendix A.3), which provides some confidence that the values derived from the registers are reasonable.

[26]The registers often did not have complete coverage for ships in the year in which they were published.

Appendix Table 7 describes the number of vessels included in the data from each of the registers used in this study.

The full data set includes just over 69,000 ships. Most of the analysis focuses on the subset of these built in the U.S. or Canada from 1851-1910. The data required extensive processing to clean and standardize location names, eliminate duplicate entries that appeared in both registers, identify the construction material for each ship, etc. After eliminating duplicates, the main analysis relies on observations for 18,700 ships built in the Great Lakes or Atlantic Coast of U.S. or Canada between 1851 and 1910. Within the regions that I study, it is possible to identify the exact location of construction for the vast majority of ships.[27]

Some summary statistics for the data on production by location used in the main analysis are reported in Appendix Table 6. Maps of the data are available in Appendix A.5. In 1901-1910, the most important period for my analysis, my data cover 160 active shipbuilding locations. While this may not appear to be a large sample size, it is comparable or larger than the sample size available in most previous studies in this literature.[28] These locations, which form the main unit of observation, are towns or cities. Most of these contained one active shipyard, though some may have contained several.[29] Of the locations in my data in 1901-1910, 74 were located on the U.S. Atlantic Coast, 60 on the Canadian Atlantic Coast, and 26 on the Great Lakes. Metal ships were being produced in 43 locations, some of which also produced wood ships, with 21 on the U.S. Atlantic Coast, 16 in the Great Lakes, and just 6 metal shipbuilding locations surviving in Coastal Canada. Thus, the majority of North American shipbuilding locations continued to focus on wood ship production.

In addition to the main data, I have also constructed several controls using Census data. I control for nearby employment in metal-working or wood-working industries using county-level Census data from the U.S. and Canada in 1880 (see Appendix A.8 for details). These

[27]For ships built in the U.S. and Canada, I am able to identify the construction location for over 99% of ship tonnage in data from the 1912 register, over 96% of tonnage in the 1889 registers. In data from the 1871 registers, the share of tonnage linked to a location within the U.S. and Canada, respectively, is 97.1% and 88.3%. The larger share of tonnage with missing locations in the Canadian data is due to the fact that only the province of construction was provided for many Canadian ships registered in the 1871 Lloyd's.

[28]For example, the analysis in Juhasz (2018) looks across 88 French Departments, while the main firm-level analysis in Irwin (2000) covers 45 firms.

[29]I use towns as the unit of observation because individual shipyards are difficult to consistently identify in the data, particularly over time.

county data are not available for Newfoundland so some observations are lost when these controls are included. Controls for iron and lumber prices at the state level, available only for the U.S., come from the Census of 1900 (see Appendix A.9 for details).

4 Main analysis

The aim of the analysis presented in this section is to establish two main results. First, that British shipbuilders developed a leading position in metal shipbuilding in the mid-19th century, a time when they enjoyed advantageous cost conditions, and that this advantage was largely maintained after the initial cost advantages disappeared in the 1890s. Second, that the failure of North American producers in certain regions to successfully transition to metal shipbuilding after their metal input costs converged to British levels can be directly linked to exposure to competition from initially-advantaged British producers. The first of these results is readily apparent from the data, so most of this section focuses on the second.

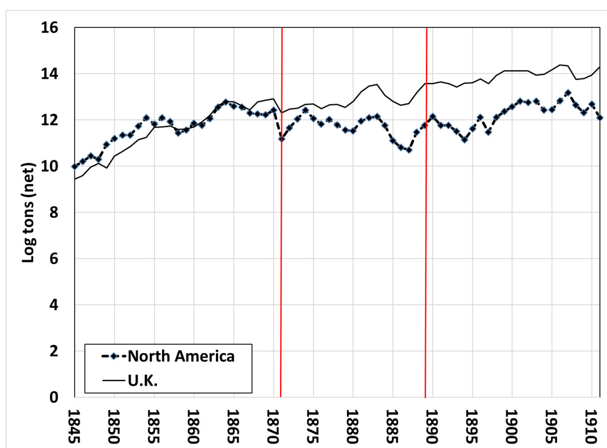
A useful starting point is Figure 2, which describes overall ship output in North America (U.S. and Canada) and Britain from 1845-1911. We can see that North America was initially the largest shipbuilding area, but it was soon surpassed by Britain. By the 1880s Britain dominated the market and this continued up to WWI despite the fact that Britain's input price advantages essentially disappeared in the 1890s.

The next set of charts, in Figure 3, can help us make sense of the overall production patterns. These graphs present output for each country divided into wood or metal ships. Here we can see that the U.K. transitioned to metal ship production early, in the 1860s and 1870s, with wood ship production essentially disappearing by the 1870s. In the U.S., the transition to metal ship production happened much later, mainly in the 1890s, when U.S. iron and steel prices were falling to U.K. levels. A third pattern is offered by Canada, where we see no evidence of a substantial move into metal ship production. Instead, most Canadian producers remained tied to the declining wood shipbuilding industry.

The key question posed by Figures 2-3 is why, after the price of metal inputs fell in the 1890s, were North American shipbuilders unable to catch up to British production levels?

One possible answer to this question is that the early lead enjoyed by British producers made them more productive and that exposure to these more productive foreign competitors made it difficult for North American producers to adopt the new metal shipbuilding technology. An alternative possibility, however, is that other factors made North America generally unsuitable for metal ship production. One way to evaluate these alternatives is to exploit plausibly exogenous variation in exposure to British competition across locations within North America that faced similar environments in other respects. Next, I provide graphical evidence describing the two key dimensions of variation that I will use to isolate the impact of exposure to foreign competition on the development of the North American industry.

Figure 2: Merchant ship production in the U.S., U.K., and Canada 1845-1911

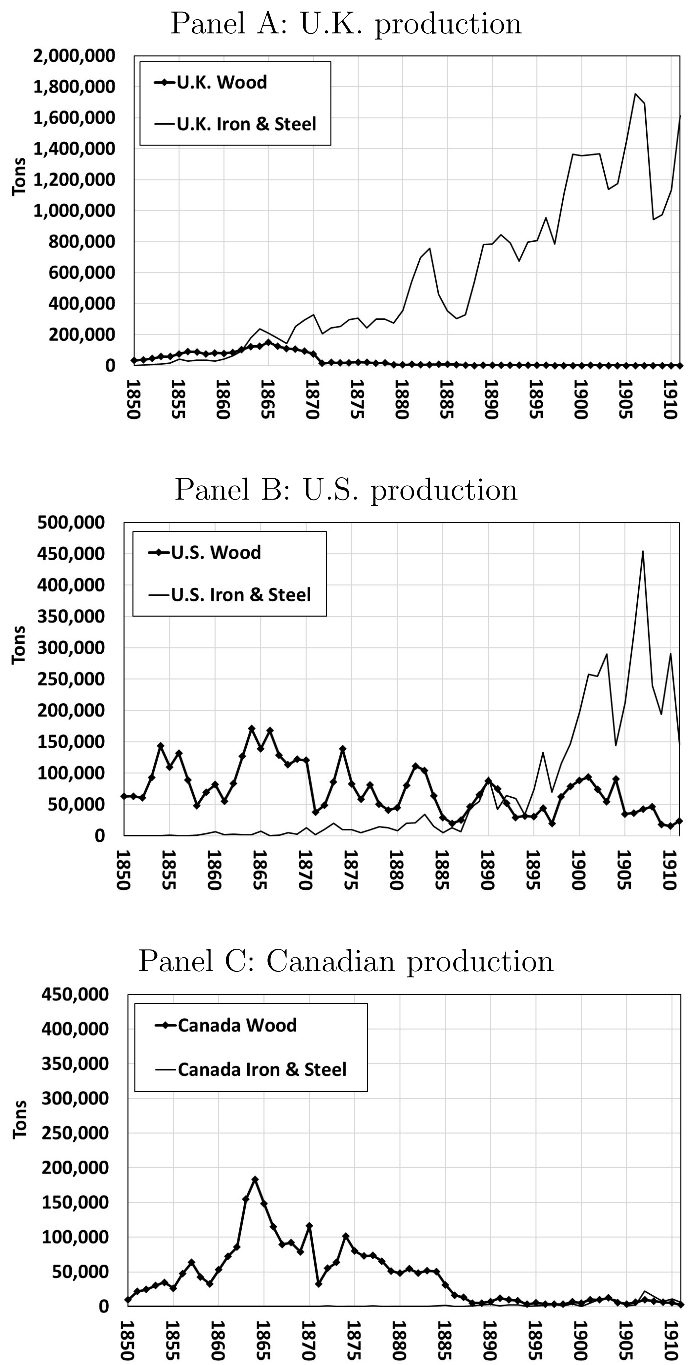


Data based on both the Lloyd's and ABS Registers. The U.K. includes all of Ireland. The U.S. and Canada data cover only the Atlantic and Great Lakes regions. The two vertical lines in this figure mark the points at which the registers providing the data switch. The fact that I do not observe sharp drops at these points suggests that I am not losing too many observations by digitizing registries every twenty years.

Figure 4 looks at the share of output (by tonnage) of metal ships in the U.K., on the Atlantic coast of the U.S. and Canada, and in the Great Lakes. The key feature to note in this graph is the production pattern observed on the Atlantic Coast of North American and the pattern observed in the Great Lakes. While the share of metal ship production was similar in these two regions until 1880, after 1880 we can see that there was a dramatic shift. Shipbuilders in the Great Lakes rapidly converged to the pattern of production observed in the overall Atlantic market (U.K., U.S. and Canada) as the price of metal inputs in North

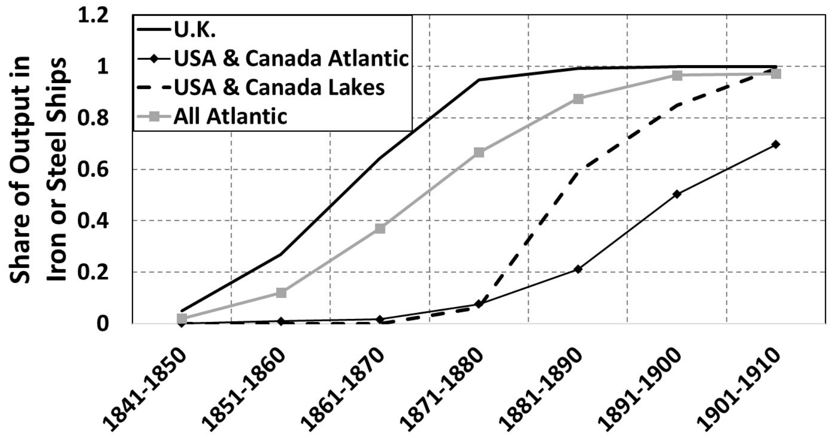
America fell, while this convergence process was much slower among North American Atlantic Coast producers. Thus, this graph reveals the impact of exposure to foreign competition on Atlantic Coast producers.

Figure 3: Shipbuilding tonnage by construction material



Data based on both the Lloyd's and ABS Registers.

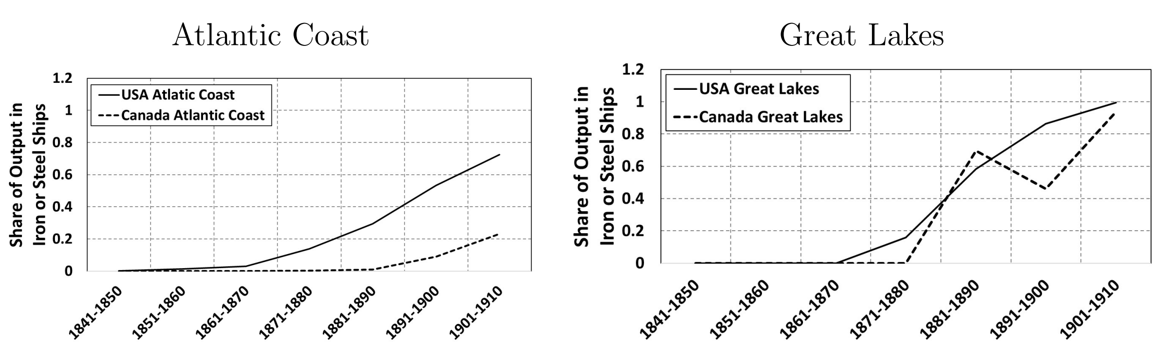
Figure 4: Evolution of production patterns by region



Data based on both the Lloyd's and ABS Registers. The U.K. includes Ireland. The "All Atlantic" category includes production in the U.K., U.S. and Canada.

Figure 5 compares shipbuilding in the U.S. and Canada to highlight the role that exposure to British competition played in the transition from wood to metal shipbuilding. The left-hand panel shows that, on the Atlantic Coast, U.S. shipbuilders transitioned to metal more rapidly than Canadian builders. In contrast, on the Lakes, where shipbuilders were more protected from foreign competition, the U.S. and Canada show similar patterns. These patterns reflect the fact that the protection offered to U.S. shipbuilders was important on the coast, while U.S. government support had less effect on the Great Lakes, where producers were already protected from foreign competition by geographic barriers.

Figure 5: Evolution of metal share on the Coast vs. the Lakes



Data based on both the Lloyd's and ABS Registers.

Overall Canadian ship production in the Great Lakes was low, even accounting for the smaller Canadian population in the lakes region. While the population of Ontario, the Canadian province bordering the Great Lakes, was equal to 7% of the population of U.S. states bordering the lakes in 1900 (or 12% if New York and Pennsylvania are excluded), Canada built only 3.8% of the tonnage produced on the Great Lakes in 1900-1910. One important factor behind this pattern was the prohibition on using foreign-built ships to serve routes connecting any two U.S. ports. Since most ports on the Great Lakes were American, a ship built in Canada would face a permanent limitation on the routes on which it could be used. On the other hand, a ship built in the U.S. still had the ability, if needed, to service routes between Canadian ports. This provided an incentive for production on the Great Lakes to take place in the U.S. rather than Canada.

However, Figure 5 shows that Canada and the U.S. exhibited roughly similar *ratios* of metal to wood ship production in the Great Lakes region.[30] The key to reconciling the protection available to U.S. producers, and their greater share in overall production, with the similar patterns shown in Figure 5 is to note that, while protection from the U.S. government benefited U.S. lakes producers, it did not specifically benefit metal ship production *relative* to wood ship production.[31] Thus, it should not affect relative production in these two sectors in the U.S. relative to Canada. In contrast, on the Atlantic Coast protection from British competition was particularly important for metal ship producers relative to wood because it was in metal ships that British competition mattered.

Next, I turn to the econometric analysis. I begin by looking at the extensive margin, i.e., whether locations were active in a particular sector (wood or metal). I then turn to the intensive margin, i.e., the amount of tonnage produced conditional on being active. The first set of results are obtained from cross-sectional regressions focused on the 1901-1910 period, after the input price differences had largely disappeared. Later, I also consider the timing of when protection mattered using the full panel of data.

To study the extensive margin, I apply multinomial logit (ML) regressions. The specifi-

[30]There were no Navy shipyards on the Great Lakes and no substantial Naval vessels were produced there.

[31]I.e., there is no evidence that U.S. Lakes producers were substantially ahead or behind Canadian Lakes producers in either sector.

cation is,

$$
\begin{aligned}
A_{ls} &= 1[a^*_{ls} > 0] \qquad (1)\\
a^*_{ls} &= \alpha_1 LAKES_l + \alpha_2 UScoast_l + X_{js}\Gamma + e_{ls}
\end{aligned}
$$

where A_{ls} is an indicator variable for whether location l was active in shipbuilding sector $s \in \{wood, metal, both\}$ in the 1901-1910 decade (with inactive as the reference category), and a^*_{ls} is an unobserved latent variable which depends on the set of explanatory variables. $LAKES_l$ is an indicator variable for whether the location is in the Great Lakes region while $UScoast_l$ is an indicator for whether the location is on the Atlantic coast of the U.S. I treat these two areas separately because they experienced varying levels of protection from British competition. The reference region is Atlantic Canada, which was fully exposed to foreign competition. The error term e_{ls} follows a logistic distribution.

Among the control variables that I consider is whether a location had been active in shipbuilding in some past decade (typically 1871-80, which avoids the decade of the U.S. Civil War but predates the input price convergence) at all, or in sector s specifically, and if so, the tonnage produced in that past decade in the location overall or in sector s specifically.[32] These controls help capture a location's physical assets for ship production such as a deep harbor or easier access to inputs. In some specifications I also control for shipbuilding in other nearby locations, county-level employment in other metal industries and lumber mills, county population, and state-level iron and wood input prices.[33] To help reduce potential endogeneity concerns with the input price controls, I use prices for products in a relatively raw state (e.g., pig iron and generic lumber) which are used as inputs in a wide variety of goods as well as shipbuilding, rather than inputs more directly related to shipbuilding (e.g.,

[32] I have explored specifications including market access as a control, following Donaldson & Hornbeck (2016). Market access measures do not seem to be correlated with shipbuilding activity. Moreover, the link between broad measures of (inland) market access and shipbuilding is not intuitively obvious. Thus, I have decided to omit market access controls from the main specifications.

[33] Shipbuilding in other nearby locations is based on data from the registers. County level employment data are from the 1880 Census. State level price data are from the 1900 Census.

steel plates).[34] The fact that shipbuilding was only one of many uses for these raw materials should limit endogeneity concerns.

One potential identification concern in this study, as well as other studies using a similar identification strategy, is that there could be some other time-varying regional shock to treated locations, such as those in the Great Lakes, that is not captured by the available control variables. In this study, the availability of two sources of plausibly exogenous variation – comparing the Great Lakes to the Atlantic and the U.S. to Canada – provides some protection against such concerns.

One may also worry about spatial correlation in my regressions. To examine this possibility, I include in all of the regression results (in square brackets) standard errors that are clustered by the 31 major shipbuilding areas during this period.[35] These clustered standard errors are presented in square brackets in the results tables in addition to the robust standard errors in parenthesis. Clustered standard errors are often similar to or slightly smaller than the robust standard errors, particularly in my preferred specifications, so I focus on the robust standard errors when indicating statistical significance (*).

Table 2 presents ML regression results based on Eq. 1. These regressions are run on the full set of U.S. and Canadian shipbuilding locations on the East Coast or Great Lakes which were active at some point in the 1850-1910 period.[36] Column 1 presents results without any additional controls while Columns 2-3 add in additional controls for activity in the location in the 1871-1880 decade, county level population and industry composition, and past production in nearby locations.[37] The results in Columns 1-3 suggest that locations in

[34]See Appendix A.9 for further details.

[35]A map describing the areas that I use is available in Appendix 14. Using shipbuilding regions is preferable to political boundaries such as states, since it ensures that nearby shipyards (e.g., New York City and Newark, NJ) are included in the same region and distant yards (e.g., New York City and Buffalo, NY) are not.

[36]An alternative approach might be to run the analysis at the county level and include all counties that bordered the lakes or the Atlantic. This approach requires that I take a stand on counties suitable for shipbuilding. This determination is not as straightforward as it seems. For example, many shipbuilders located on rivers, while many coastal counties with rugged coastlines or in the north of Canada were unlikely shipbuilding locations. Thus, a sample of coastal counties is likely to include many counties that were unsuitable for shipbuilding, which really shouldn't be in the sample.

[37]Of the controls included in the regressions in Table 2, the most explanatory are the indicators for whether a location was active in a particular sector in 1870. The other consistently significant control variable is county population, which is positively related to whether a location was active in both metal and wood ship production (outcome three).

the Great Lakes were more likely to be active in the production of metal ships, either alone or in combination with wood shipbuilding, relative to exiting the market. There is also some evidence that coastal locations in the U.S. were more likely to remain active, but this result does not remain significant as controls are added.

It is worth noting that adding in controls for previous production in Columns 2-3 affects the interpretation of the results. Without controlling for past production patterns, the estimates in Column 1 should capture the impact of both current protection from foreign competition as well as the effect of protection in the past operating through learning effects. Adding in past production patterns helps control for locational advantages in a particular type of shipbuilding, but these controls will also soak up some of the effect of past protection operating through learning. Since I am primarily interested in the impact of protection in the period after which the gap between British and North American input prices had narrowed, my preferred results are those that include controls for production patterns in the 1870s.

In Columns 4-5 I include additional controls for state-level iron and lumber prices. Note that these data are available only for the U.S., which means that fewer observations are available for these regressions and I cannot compare the U.S. coast to Canada. Despite the smaller sample size, I still tend to find evidence that locations in the Great Lakes were more likely to be active in metal shipbuilding than those on the coast. It is worth noting that these results are identifying the effect of the additional protection provided by being in the Great Lakes (and in the U.S.) compared to being in the U.S. but on the coast.

At the bottom of the table I include additional tests comparing the probability of being active in metal shipbuilding or in both sectors to the probability of being active in wood shipbuilding alone. These tests are important because comparing metal to wood ship production in the Great Lakes helps me deal with concerns that the results are just reflecting more rapid growth in shipbuilding in the Great Lakes overall. In general, the effect of the Great Lakes on whether a location is active in metal (in combination with wood) is statistically different from the impact of the Great Lakes on activity in wood only.

Table 2: Multinomial logit regression results

	(1)	(2)	(3)	(4)	(5)
A=1: Location active in wood shipbuilding only in 1901-1910					
U.S. Coastal	-0.082	0.009	0.268		
	(0.209)	(0.228)	(0.412)		
	[0.379]	[0.402]	[0.445]		
Great Lakes	0.324	0.603	0.542	0.282	0.241
	(0.382)	(0.418)	(0.460)	(0.610)	(0.649)
	[0.371]	[0.378]	[0.429]	[0.487]	[0.560]
A=2: Location active in metal shipbuilding only in 1901-1910					
U.S. Coastal	0.630	1.049	0.316		
	(0.712)	(0.902)	(1.064)		
	[0.834]	[0.818]	[0.899]		
Great Lakes	2.991***	1.671*	1.351	1.479*	1.790*
	(0.697)	(0.848)	(0.941)	(0.737)	(0.786)
	[0.756]	[0.745]	[0.746]	[0.830]	[0.866]
A=3: Location active in both wood and metal shipbuilding in 1901-1910					
U.S. Coastal	1.546*	2.554**	0.771		
	(0.637)	(0.842)	(1.151)		
	[0.536]	[1.016]	[1.383]		
Great Lakes	2.991***	4.655***	3.265**	3.423***	2.873**
	(0.697)	(0.941)	(1.139)	(0.815)	(0.915)
	[0.597]	[1.084]	[1.418]	[0.622]	[0.764]
Observations	833	833	779	274	274
Testing effect on A=2 different from A=1 (p-values, robust SEs)					
U.S.	0.3315	0.2599	0.9801		
Great Lakes	0.0004	0.2420	0.4264	0.1832	0.1074
Testing effect on A=3 different from A=1 (p-values, robust SEs)					
U.S.	0.0138	0.0030	0.6867		
Great Lakes	0.0004	0.0000	0.0224	0.0009	0.0107

*** p<0.01, ** p<0.05, * p<0.1 based on robust SEs, shown in parentheses. Standard errors in brackets are clustered on shipbuilding area. The analysis covers all locations active in shipbuilding from 1850-1910 in in the Atlantic Coast or Great Lakes regions of the U.S. and Canada. Column 2 includes controls for whether a location is active in metal or wood shipbuilding in 1870 as well as separate variables for tonnage produced in metal or wood in 1870. Column 3 adds additional controls for metal or wood shipbuilding at other locations within 100km, county log population, the county employment share in metalworking industries, and the employment share in lumber. Note that the county data are not available for some locations. Column 4 includes the controls in Column 2 together with the log price of pig iron and log lumber index price in the state. These are only available for a subset of U.S. states, so the number of observations drops substantially. Column 5 includes the controls in Column 4 together with controls for county log population, the county employment share in metalworking industries, and the employment share in lumber. Tests of coefficient differences use robust SEs.

The results in Table 2 are consistent with the idea that North American shipbuilders that were not exposed to British competition were able to rapidly switch to metal shipbuilding once metal input prices fell. This suggests that it was exposure to initially advantaged British producers, rather than other factors, that were likely behind the inability of Coastal North America shipbuilders to catch up to their British competitors after 1900.

Two additional sets of ML results are available in Appendix A.15. The first considers both the ship's construction material and power source (sail vs. steam). These results show that differences in metal ship production between the Lakes and the Coast were not driven by differences in demand for sailing vs. steamships. The second set of results treats the U.S. and Canadian areas of the Great Lakes regions separately and shows that both areas exhibit fairly similar patterns, though the relatively small number of Canadian Great Lakes shipyards means results for that group are imprecise.

Next, I study the intensive margin of production, i.e., how much tonnage a shipyard produced from 1901-1910 in a sector conditional on being active in that sector. I use:

$$\begin{aligned} \ln(Y_{ls}) &= \beta_0 METAL_s + \beta_1 LAKES_l + \beta_3 UScoast_l \\ &+ \beta_4(METAL_s \times LAKES_l) + \beta_5(METAL_s \times UScoast_l) + X_{js}\Gamma + \epsilon_{js} \end{aligned} \quad (2)$$

where Y_{ls} is ship tonnage of type s produced in location l, $METAL_s$ is an indicator for the metal ship sector, and the remaining variables are defined as before. The main coefficients of interest in this regression are β_4 and β_5 which reflect the impact of being in the Great Lakes market or in the U.S., respectively, on metal ship output relative to wood. I use log tonnage as the dependent variable in these regressions, but similar results are obtained if instead I use the level of tonnage (Appendix Table 16). This tells us that the results are not being driven by the fact that the log specification places more weight on smaller observations.

Table 3 presents the results of regressions based on Eq. 2. Column 1 presents baseline results while Columns 2-3 add in additional controls following the same format as in Table 2. Columns 4-5 present results including state-level price controls and using only observations from the U.S.[38] These results suggest that, conditional on a location being active in a particular sector, tonnage of metal ship production was higher in locations in the Great Lakes region and in the Coastal U.S. compared to Coastal Canada. The magnitudes of these effects are large; being in the Great Lakes is associated with an increase in tonnage of 4-5 log points relative to Coastal Canada and about 2 log points relative to the Coastal U.S. (Columns 4-5). Being in the Coastal U.S. is associated with a tonnage increase of about 2 log points relative to Coastal Canada.[39] Additional results, in Appendix A.16 show that these patterns are being driven entirely by steamships. Moreover, the impact of the Great Lakes and the U.S. markets continues to hold when we look only within steamships, so these effects are not being driven by a different mix of steamships vs. sailing ships in different markets.

In Appendix A.16 I look at whether similar results to those shown in Tables 2-3 are obtained if we look at the impact of being in the Great Lakes within only the U.S. or only Canada, or the impact of being in the U.S. in only the Lakes or only the Atlantic. I find that locations in the Great Lakes produce more metal ship tonnage in 1901-1910 in both the U.S. and Canada, but the protection afforded by the Lakes is more important for Canadian shipbuilders. Focusing only on the Atlantic Coast, I find evidence that shipyards in the U.S. produced more metal ship tonnage, while I find no strong evidence that being in the U.S. mattered in the protected Lakes market (though the small number of Canadian shipyards on the Great Lakes means that these results should be interpreted with some caution).

[38]A table displaying the estimated coefficients for all of the controls variables is in Appendix A.16.
[39]Mean production in active metal shipbuilding locations in the data in 1901-10 was 66,000 tons.

Table 3: Tonnage regression results

DV: Log of tons in 1901-1910 by location and material					
	(1)	(2)	(3)	(4)	(5)
Great Lakes x Metal	5.174***	4.802***	4.703***	2.522***	2.547***
	(0.731)	(0.798)	(0.811)	(0.895)	(0.887)
	[0.775]	[0.752]	[0.738]	[0.691]	[0.729]
U.S. Coast x Metal	2.467***	2.204***	2.396***		
	(0.700)	(0.714)	(0.782)		
	[0.942]	[0.694]	[0.705]		
Metal indicator	Yes	Yes	Yes	Yes	Yes
U.S. Coast ind.	Yes	Yes	Yes		
Great Lakes ind.	Yes	Yes	Yes	Yes	Yes
Activity in 1871		Yes	Yes	Yes	Yes
Tonnage in 1871		Yes	Yes	Yes	Yes
Nearby tons in 1871			Yes		
County controls			Yes		Yes
Input prices				Yes	Yes
Observations	186	186	182	82	82
R-squared	0.427	0.516	0.551	0.620	0.640

*** p<0.01, ** p<0.05, * p<0.1 based on SEs clustered by location, shown in parentheses. Standard errors in brackets are clustered on shipbuilding area. Regressions are run only on sector-locations that were active in 1901-1910. Column 2 includes controls for whether a location is active in metal or wood shipbuilding in 1870 as well as separate variables for tonnage produced in metal or wood in 1870. Column 3 adds additional controls for metal or wood shipbuilding at other locations within 100km, county log population, the county employment share in metalworking industries, and the employment share in lumber. Note that the county data are not available for some locations. Column 4 includes the controls in Column 2 together with the log price of pig iron and log lumber index price in the state. These are only available for a subset of U.S. states, so the number of observations drops substantially. Column 5 includes the controls in Column 4 together with controls for county log population, the county employment share in metalworking and the share in lumber.

Next, I look at the timing of the effects using the full panel of data, focusing on the intensive margin of production. The specification is,

$$\begin{aligned} Y_{lst} &= \sum_t \beta_{0t}(METAL_s \times D_t) + \sum_t \beta_{1t}(LAKES_l \times METAL_s \times D_t) \\ &+ \sum_t \beta_{2t}(LAKES_l \times WOOD_s \times D_t) + \sum_t \beta_{3t}(US_l \times METAL_S \times D_t) \\ &+ \sum_t \beta_{4t}(US_l \times METAL_S \times D_t) + X_{jst}\Gamma + \sum_t \eta_t D_t + \phi_{ls} + \epsilon_{js} \end{aligned} \tag{3}$$

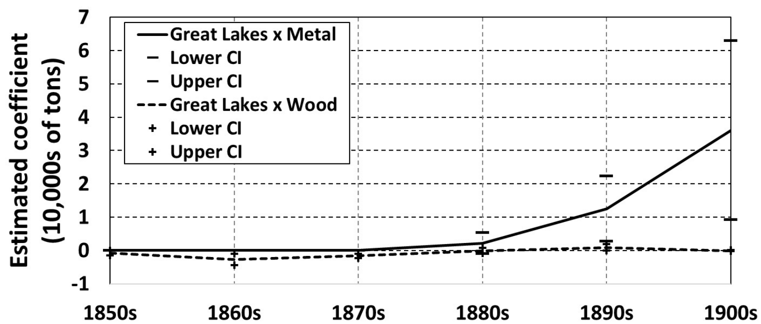
where Y_{lst} is ship tonnage (in 10,000s), $WOOD_s$ is an indicator variable for the wood shipbuilding sector, D_t is a set of indicator variables for each decade, and ϕ_{ls} is a set of fixed effects for each sector-location. These regressions allow me to look at the impact of being in the Great Lakes or in the U.S. on iron ship output while controlling for changes in output over time as well as differences in regional production patterns over time. Because of concerns about serial correlation in these regressions, standard errors are clustered by location. I focus on tonnage rather than log tons in this specification to avoid dropping observations for locations that were inactive (produced zero tons) in at least some decades. The coefficients of interest in Eq. 3 are the vectors β_{1t} - β_{4t}, which reflect the impact of being in the Great Lakes or being in the U.S. in each decade within each ship type. These estimates, together with 95% confidence intervals, are described in Figure 6.

The top panel of Figure 6 shows the coefficients estimated for each decade on the interaction between the Great Lakes and either metal or wood shipbuilding. These results suggest that being located in the Great Lakes was, if anything, associated with lower production tonnage prior to the 1880s. Then, starting in the 1890s, there was a relative increase in tonnage produced on the Great Lakes which was concentrated in metal shipbuilding.[40] This timing corresponds with the fall in U.S. iron and steel prices as well as an increase in demand for Great Lakes shipping. The bottom panel shows that starting in the 1890s metal shipbuilding experiencing a relative increase in the Coastal U.S. compared to Coastal Canada. This timing corresponds to the fall in metal prices and the expansion of the U.S. Navy.

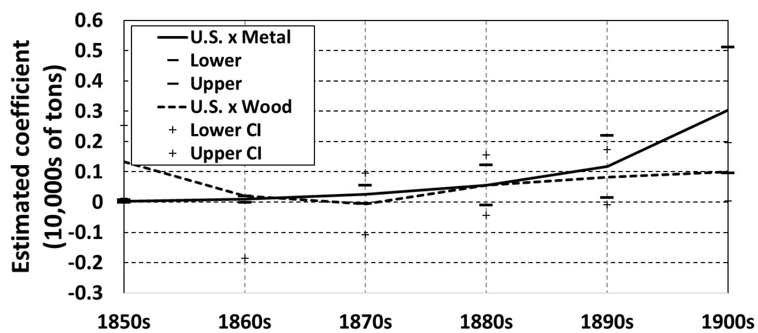
[40]In terms of magnitude, the estimated effect of being in the Great Lakes or the U.S. in Figure 6 are somewhat smaller than those obtained from cross-section tonnage regressions in Appendix Table 16. In particular, the cross-sectional results suggest that Great Lakes locations produced around 120,000 more metal tons and U.S. locations produced around 40,000 additional metal tons. The panel results suggest that Great Lakes locations produced around 30,000 additional metal tons and U.S. Coast locations produced around 3,000 tons after 1900.

Figure 6: Panel data regression results

Coefficients for (Lakes × Metal) and (Lakes × Wood)



Coefficients for (U.S. Coast × Metal) and (U.S. Coast × Wood)



Estimates based on decadal data from 1850-1910. Figures show coefficients for the interaction of an indicator for metal shipbuilding with an indicator for the Great Lakes (top panel) or the U.S. (bottom panel) on tons produced (in 10,000s) and similar coefficients for interactions using an indicator for wood shipbuilding. Regressions include decade effects and a full set of location-by-sector fixed effects. 95% confidence intervals based on standard errors clustered by location.

One potential concern with this analysis is that there may have been other initial differences that gave some locations an advantage in metal ship production relative to others. One way to provide some additional evidence on this point is to focus on a set of very similar locations that differed in their exposure to competition. A natural candidate is to compare shipyards in Maine to those in Nova Scotia and New Brunswick. These three areas were all major wood shipbuilding centers in the late 19th century and none of these locations had meaningful metal ship production prior to the 1880s. Their economies were also similar in a number of other respects (see details in Appendix A.17). However, only shipyards in Maine enjoyed protection from British competition, while those in nearby Nova Scotia and New Brunswick were not protected.

Figure 7 compares the evolution of wood and metal shipbuilding in these similar locations. Both areas show similar patterns of wood ship production, with output peaking in the 1860s and then declining starting in the 1870s, though the decline in wood ship output was not as steep in Maine due to the protection afforded by U.S. policies. The key feature in this graph is the pattern of metal ship production. Despite the initial similarity of these areas, only in Maine do we see the emergence of any substantial metal ship production. The fact that the patterns identified in the broader statistical analysis also emerge when focusing only on these initially very similar shipbuilding areas provides confidence that the broader results are not being driven by initial differences. Instead, a locations chances of successfully switching from wood to metal ship production appears to be closely linked to the extent to which the location was exposed to foreign competition.

Figure 7: Evolution of shipbuilding in Maine vs. Nova Scotia/New Brunswick

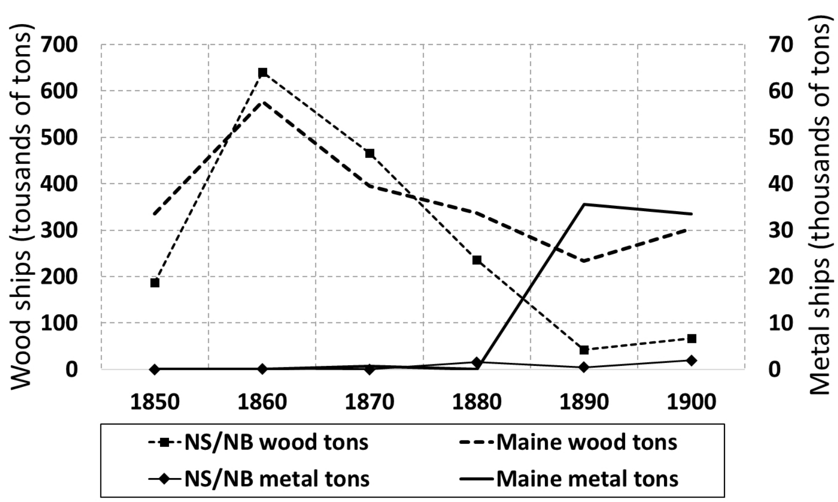


Figure compares wood tonnage (left axis) and metal tonnage (right axis) produced in Maine (USA) to tonnage produced in Nova Scotia and New Brunswick (Canada).

As a final piece of this analysis, it is useful to consider the key margins for competition between British, U.S. and Canadian shipbuilders. The data make it clear that competition between British and U.S. shipbuilders was not mainly over sales of vessels to shipping companies based in those countries. Most (91%) the vessels homeported in the U.S. were built there (7.6% of tonnage homeported on the U.S. Atlantic Coast was built in Britain), and essentially all of the tonnage homeported in Britain in 1912 was also produced there.[41] Instead, the key margin of competition was the market for vessels operated by firms in other countries that served the U.S. market. We can study this group by looking at vessels registered in the U.S.–presumably because they were serving U.S. ports–but homeported outside of the U.S., Canada, and Britain. This was a large market because there were many countries where the needs of shipping firms substantially exceeded the capacity of local shipbuilding (e.g., Greece, Italy, Brazil, the Netherlands).[42]

Table 4 uses data on homeport location digitized from the 1912 ABS registry to identify the construction location of ships homeported outside of the U.S., U.K. and Canada. Since these data come from the ABS–a U.S. registry–it is likely that at some point these ships were active in serving North American ports, so if anything we would expect U.S. shipbuilders to have some advantage relative to British producers. Despite this, the data show that British producers were dominant in supplying ships based outside of the U.S., U.K. and Canada. Moreover, there is little change in this pattern when British colonies are excluded. Nor does the pattern appear to be driven by ships that were re-sold by their original owners; if I focus only on ships built recently, which are likely to still be held by their original owner, there is little change in the results. Thus, British dominance was not linked mainly to the size of their own merchant marine relative to American merchant marine, but rather to their ability to dominate sales to shipping firms based in other countries that served the U.S. market.

The same pattern does not hold for Canada, where there was no restriction on Canadian shipping firms using British-built ships. There, the data show that even a large fraction of vessels homeported in Canada had been built in Britain (see Appendix table 9). Thus, the key margin for competition between Canadian and British shipbuilders was not the third party market, but instead sales to Canadian shipping firms. This reflects the key difference

[41] Statistics are for ships registered in the 1912 ABS registry. See Appendix Table 9 for further details.

[42] Of the tonnage registered in the 1912 ABS, 32% was homeported outside of the U.K., U.S. or Canada. Of this, 60%, just over 4 million tons, was built in a country other than the homeport country. As a point of comparison, total tonnage homeported in the U.S. was just over 5 million tons. Thus, the contested third-party market available to U.S. shipbuilders was almost as large as the total domestic market.

Table 4: Source of vessels in the American registry homeported outside of the U.K., U.S. and Canada

	All ships in 1912 ABS		Newer ships in 1912 ABS	
	Ships homeported in:		Ships homeported in:	
Country of construction:	All foreign locations	Foreign locations except British colonies	All foreign locations	Foreign locations except British colonies
U.K.	55.65%	54.95%	48.57%	47.54%
U.S.	0.51%	0.52%	0.09%	0.09%
Canada	0.09%	0.07%	0.02%	0.00%
All others	43.74%	44.46%	51.32%	52.37%

Data from the 1912 ABS registry. Newer ships are those built after 1904. Note that the increase in the "All others" share when focusing only on newer ships suggest that other countries were gaining market share during this period. These gains were driven primarily by Germany, where the government was subsidizing shipbuilding during this period, as well as by increase in Japan and Italy.

between the protection afforded U.S. shipbuilders and the lack of protection available to Canadian shipyards.

The main conclusion to draw from this section is that exposure to competition from initially advantaged British producers substantially retarded the ability of North American shipbuilders to transition to metal ship production. These econometric results are reinforced by historical evidence. In 1897, for example, the *Baltimore Journal of Commerce* wrote of the U.S. shipbuilding industry, "on the lakes, where it receives the most effective protection, the ship building industry enjoys its highest prosperity and reaches its most splendid proportions; whereas on the ocean, where it has no protection at all, it is gradually falling into decay under the aggressive competition of more enterprising nations."[43] Whether the transition from wood to metal was made determined the ultimate success of the industry in each location as wood shipbuilding disappeared in the early 20th century.

[43]Quoted from the Marine Review, Oct. 28, 1897.

5 Evidence of learning

The results in the previous section suggest that North American shipyards were unable to compete with British producers even after Britain's initial advantage in input prices had disappeared. This tells us that British producers enjoyed some persistent productivity advantage. One explanation for this pattern is that the shipbuilding industry may be characterized by dynamic learning effects, so that current productivity is increasing in previous production experience. Such effects would explain why Britain's initial lead meant that, later on, North American shipyards exposed to British competition had trouble entering metal shipbuilding.

Learning can take many forms, but these forms can be roughly divided into those types that are internal to firms and those that are external. Organizational improvements resulting from experience, for example, represents an internal form of learning, while the acquisition of skills by workers is external to firms, since workers can switch jobs. Distinguishing between these forms can therefore shed light on the types of mechanisms likely to be behind the broad patterns documented in the previous section.

There is already existing evidence suggesting that the shipbuilding industry was characterized by learning effects (e.g., Thompson (2001), Thornton & Thompson (2001)). However, this existing evidence does not distinguish whether the learning was internal or external to an individual yard, or whether external effects were localized.[44] Also, because these results come from wartime shipyards, which sought to rapidly produce many ships with a common design, it is unclear the extent to which these results carry over to peacetime yards, which rarely produced more than a couple ships of a given type. Thus, more evidence is needed to understand the nature of learning in this industry.

The section uses the location of U.S. Navy shipyards to provide evidence that learning was important in the shipbuilding industry, and that at least part of this learning was external to individual shipyards. Proximity to U.S. Navy Shipyards could benefit nearby private-sector shipyards through technology spillovers or by providing access to pools of skilled metal

[44]This issue has been studied by Thornton & Thompson (2001), but their analysis uses a relatively small number of geographically dispersed yards which makes it impossible for them to look for evidence of geographically localized spillovers.

shipbuilders.[45] To identify these effects, I take advantage of the fact that the location of Navy shipyards was plausibly unrelated to a location's specific advantage in metal, relative to wood, shipbuilding. This is a plausible assumption because the locations of the Navy shipyards in operation during the period that I study (shown in the map in Appendix Figure 22) were all determined around 1800, well before the introduction of metal ships.[46] Thus, while Naval shipyards were situated in locations with advantages for shipbuilding overall, there is little reason to believe that they were sited in locations that were particularly advantageous for metal shipbuilding after 1880.

Results looking at the impact of proximity to U.S. Navy shipyards are presented in Table 5. These are based on the set of U.S. Atlantic Coast shipyards only.[47] The regressions are run using log tonnage regression specification from Eq. 2. Columns 1-3 present results using all U.S. Atlantic coast locations. All of the results suggest that close proximity to a Navy shipyard – within 50km – has a positive relationship to the tonnage of metal ships produced. The impact of proximity to Navy shipyards on wood shipbuilding tends to be negative, suggesting that private shipyards near the Navy yards were more likely to switch from wood to metal ship construction, or that metal shipbuilding pushed wooden shipbuilding out of these locations. Column 4 shows that these effects were localized and disappear beyond 50km.

In Appendix A.18 I show that these basic results are robust to using a variety of alternative samples or control variables. For example, similar results are obtained if I focus only on locations that were active in wood shipbuilding in 1870s. This is important because

[45]Proximity to Navy Yards may have also improved access to Navy contracts, which could have had beneficial effects that spilled over into the construction of merchant ships within yards. In the robustness exercises in Appendix A.18 I present results from a specification that includes a control for whether each private shipyard received Navy contracts.

[46]The five Naval shipyards in operation during the period I study were in Portsmouth, VA (Norfolk NSY, opened 1767), Boston, MA (opened 1800), New York City (Brooklyn NSY, opened 1800), Philadelphia (opened 1801), and Kittery, ME (Portsmouth NSY, opened 1800). The only other early Atlantic shipyard, in Washington, DC, was opened 1799 but this yard largely ceased ship construction after the War of 1812 because the Anacostia River was too shallow to accommodate larger vessels. A Coast Guard shipyard was opened in Baltimore in 1899, but I do not include that in my analysis because it is likely that the location of that yard was influenced by Baltimore's potential for metal shipbuilding.

[47]There are 74 U.S. Atlantic Coast shipyards in this analysis some of which are active in both wood and metal shipbuilding, yielding a total of 89 location $\times$ material observations. Of these locations, 24 were located within 50km of a Navy shipyard, 39 were located from 50-100km from a Navy shipyard, and 11 were more than 100km from a Navy shipyard.

it reduces the possibility that the results could be do merely to selection, i.e., that more productive metal shipyards may have chosen to locate closer to Navy Shipyards.

One may also worry that locations near Navy shipyards had better infrastructure connections. Naturally, all shipyards had good access to water transport, but railroad connections may have varied. I have examined the railroad connections of the U.S. shipyard locations using the data produced by Jeremy Atack (2016). These data show that all of the shipyard locations had railroad connections before 1890, with the exception of a few small island locations in Maine or Massachusetts (see Appendix Figure 15). Since my results are not sensitive to dropping these states from the analysis (see Appendix A.18), differences in infrastructure connections are unlikely to be behind the effects of proximity to Navy shipyards that I estimate.

In the Appendix, I also present ML results which show that locations near Navy yards were somewhat more likely to be active in the 1901-10 period but that this effect was not differential for wood vs. metal shipbuilding. This provides additional evidence that the main impact of Navy shipyards was on the intensive margin and that selection is not likely to be a driving force behind my results. I also show that the effect of Navy shipyards survives even when controlling for whether a yard received Navy contracts, though the magnitude falls. This suggests that at least a substantial portion of the effect of proximity to Navy shipyards was due to factors other than access to Navy contracts. Finally, I show that my results are not being driven by any one shipbuilding region.

To summarize, the results in this section suggest that learning that was external to firms was a salient feature of the shipbuilding industry. This provides some indication of the mechanisms behind how Britain's initial advantage generated a persistent lead in the shipbuilding industry. In the next section I draw on historical evidence to shed further light on the nature of this learning.

Table 5: Results looking at the impact of proximity to U.S. Navy Shipyards

DV: Log of tons in 1901-1910 by location and material				
	(1)	(2)	(3)	(4)
Navy yard within 50km x Metal	2.761**	2.381**	2.390**	3.093**
	(1.044)	(1.006)	(1.051)	(1.378)
	[0.955]	[0.790]	[0.790]	[1.385]
Navy yard within 50km	-1.178**	-1.280***	-1.344***	-0.737
	(0.473)	(0.370)	(0.527)	(0.711)
	[0.504]	[0.286]	[0.286]	[0.358]
Navy yard within 100km x Metal				-0.806
				(1.252)
				[1.449]
Navy yard within 100km				-1.065
				(0.717)
				[0.693]
Metal ind.	Yes	Yes	Yes	Yes
Controls for active in 1870s		Yes	Yes	Yes
County controls			Yes	Yes
Observations	89	89	89	89
R-squared	0.281	0.463	0.475	0.504

*** p<0.01, ** p<0.05, * p<0.1 based on SEs clustered by location, shown in parentheses. Standard errors in brackets are clustered on shipbuilding area. Regressions are run on data from U.S. Atlantic Coast locations only. All regressions include controls for whether the sector was metal. The regressions in Columns 2-4 also include controls for whether a location was active in 1871-1880, whether it was active in the same sector in 1871-1880, total tonnage produced in the location in 1871-1880, and tonnage produced in the same location and sector in 1871-1880. Regressions in Columns 3-4 include county-level controls for log population, metalworking employment share and lumber milling employment share.

6 A Discussion of the Channels

The previous section provides evidence that the shipbuilding industry was characterized by dynamic learning effects which were external to firms. In this section I draw on historical sources to shed some additional (suggestive) light on the specific mechanisms likely to be at work in this context. A good starting point for this exploration is to consider the types of mechanisms suggested by existing theories. These include productivity advantages gained through learning-by-doing in general (Krugman, 1987; Young, 1991) or learning that was specifically embodied in worker skills (Lucas, 1988, 1993; Stokey, 1991), through an R&D

lead (Grossman & Helpman, 1991), or through achieving internal economies of scale.

Two of these channels can be discarded at the outset. An explanation based on internal economies of scale is inconsistent with the highly competitive and fragmented nature of the shipbuilding industry. Also, historical sources indicate that shipyards typically did not invest in R&D, most likely because the highly competitive nature of the industry left them with little surplus to invest, while the ease of copying give them little incentive.[48] In addition, sources such as Pollard & Robertson (1979) indicate that U.S. shipyards were actually developing and using more advanced technologies, such as hydraulic riveters and larger cranes, than British yards by the early 20th century.

Of the remaining channels, available historical evidence points to the development of pools of skilled metal shipbuilders as the key factor that translated Britain's initial advantages into a persistent lead. As Pollard & Robertson (1979) write in their authoritative history of the British shipbuilding industry (p. 129), "While foreign builders were able to choose better sites and design more efficient yards and shops, they were unable to overcome completely the greater efficiency of British labor, an efficiency that in part derived from Britain's longer tradition as a producer of iron and steel steamships."

One aspect of this channel was the vital importance played by labor costs, and skilled labor costs in particular, in the industry. In 1877 *Scientific American* reported that for metal ships, "The greatest [cost] item, however, is labor, the cost of which constitutes fully 60% of that of a steamer, and at least 50% of that of a sailing vessel; or starting with the pig iron and sawn lumber, it is estimated to amount to 80% per cent..."[49] Similarly, in 1893 Hichborn (1893) indicates that labor accounted for 69% of the cost of constructing the Navy cruiser Charleston.

Most of this labor cost came from skilled craft workers. In British yards these workers

[48]For example, Pollard & Robertson (1979) write that (p. 148), "Many improvements, if not most, however, were developed outside of the industry, in the steel-making, electrical products, or engineering industries...it was only necessary for the shipbuilders to adopt innovations after the basic research had been done elsewhere. Few laboratories were established in the yards, and as the reluctance to use experimental tanks [to test ship designs] demonstrates, builders were not even very interested in investing funds to solve problems peculiar to their industry."

[49]sci (1877).

made up 70-80% of the workforce.[50] A wide variety of specialized skills were required for the production of large metal ships, including riveters, tinsmiths, boilermakers, carpenters, plumbers, riggers, fitters and draftsmen.[51] While some of these skilled were also applicable in sectors other than shipbuilding (so called "amphibians") and others were used in both wood and metal ship production (e.g., carpenters and riggers), many important skills were unique to metal shipbuilding. For example, the skills involved in bending and shaping large metal plates into curved and irregular shapes were unique, and vital, to metal shipbuilding. One factor that increased the importance of skills is the fact that the vast majority of ships were bespoke products produced to designs supplied by the buyer.[52] This increased the need for skilled workers who could move flexibly between different ship types.[53] Skills were acquired primarily through experience. In Britain, this typically meant formal apprenticeships lasting 5-7 years. Only a very small subset of the most skilled workers, such as marine engineers and naval architects, had any formal education.[54]

In contrast to British yards, evidence suggests that North American producers wishing to begin metal shipbuilding in the late 19th century faced a scarcity of experienced metal shipbuilders. Pollard & Robertson (1979) describe how, to compensate for the lack of skilled workers, North American shipyards used more capital in order to substitute toward unskilled workers. Unfortunately for these yards, "expensive equipment could not compensate for the lower level of skills and more irregular output...Thus, despite Britain's inferior capital equipment, the output per man hour was still highest in Britain at the end of the [19th] century." While, "In the United States, vast overheads crippled builders in all but the best years. British yard owners were able to take advantage of their more highly skilled workforces by investing only in equipment that was absolutely necessary...and by refusing to purchase as many labor-saving machines as German and American builders did." Consistent with this,

[50] Pollard & Robertson (1979) (Table 8.1, p. 153) show that in 1892 unskilled workers made up 29% and 22% of the labor force in English and Scottish shipyards, respectively, 18% in Scottish yards in 1911, and 25% in Northeast England in 1913.

[51] See Pollard & Robertson (1979) p. 78.

[52] Pollard & Robertson (1979) write (p. 152), "...the fact that they [shipbuilders] produced for the most part a large, custom-made commodity that was not susceptible to many of the techniques of mass production, ensured that a premium continued to be placed upon skilled labor."

[53] This represents an important difference relative to the Liberty shipbuilders studied in previous work, who focused on producing standardized designs.

[54] See Pollard & Robertson (1979) for more details.

Hutchins (1948) found that (p. 50), "American shipyard work which could be effectively mechanized cost no more than that in Britain, but handicraft work, of which there was a large amount, was much more expensive." Thus, despite using more capital and advanced technology, evidence suggests that the lack of skilled workers meant that the cost of producing most merchant ship types in North American yards was much higher than in Britain.[55]

One illustration of the challenges faced by North American shipyards is provided by the 1905 *Report of the Merchant Marine Commission* to Congress. This report provides the following example:

> *Convincing proof on this point was offered in 1900, when steel plates and beams, because of labor troubles abroad, were selling at $40.86 in England, and $28 in the United States. Boston shipowners at that time invited bids from an American and a British builder for a cargo steamship of about 5,000 tons capacity. With both yards figuring for a small competitive profit, the American estimate was $275,000 and the English $214,000. The material of the American ship would have cost $63,000; of the English ship, $80,000. But this difference was more than offset by the higher wages paid to the American shipyard mechanics.*

The higher wages in U.S. yards do not appear to be a result of union activity. Unions were strong in British shipyards, but largely absent from American shipyards before WWI. As one American shipyard superintendent wrote after visiting British yards in 1897, "in my judgment, the worst feature today of the British yards is the tremendous power of the labor unions... the exactations and obstructions of all kinds that are thrown about the work by these unions is almost inconceivable" in contrast with U.S. yards where, "we manage our own business...the union and the walking delegate are not all powerful."[56] This suggests that, if anything, union activity should have given U.S. yards and advantage.

It also does not appear that the U.S. experienced a shortage of those very high-skilled

[55]Hutchins (1948), for example, suggests that (p. 47), "British costs were from 30 to 40 percent less." The *Report of the Merchant Marine Commission* found that in 1905 the difference was 30 to 50 percent (p. viii).

[56]This quote is from W.I. Babcock of The Chicago Ship Building Company, writing in the *Marine Review*, Sept. 2, 1897.

workers in jobs, such as naval architect or marine engineer, that required formal education. Pollard & Robertson (1979) report that by the early 20th century the U.S. was turning out more university-trained ship designers than Britain, from places like Cornell, MIT, and the Webb Institute. Instead, the key constraint appears to have been the much larger body of craft workers that relied on skills gained through experience, rather than in the classroom.

There is also evidence that a scarcity of skilled labor was the key constraint in Atlantic Canada. For example, focusing on the Maritime Provinces, Sager & Panting (1990) write that (p. 12), "The best contemporary estimates were that Nova Scotia possessed all the necessary advantages for steel shipbuilding except skilled labor." This is a telling statement, particularly given that Nova Scotia had been one of the foremost (wood) shipbuilding areas in the mid-19th century.

Additional evidence on the scarcity of skilled metal shipbuilders in the U.S. in the late 19th Century is offered by Hanlon (2019), which uses census data to study the composition of the workforces in two U.S. Atlantic Coast shipyards that successfully transitioned into metal shipbuilding, Newport News Shipyard in Virginia and Bath Iron Works in Maine, as well as one Great Lakes shipyard in Loraine, OH. That study shows that, early in their life, these shipyards substituted away from skilled workers toward unskilled workers and capital and relied on immigrants from Britain to fill key skilled positions that could not be eliminated. Once established, these yards began to train native-born workers to fill skilled positions.

7 Conclusions

The experience of the international shipbuilding industry documented in this study offers a window into understanding how temporary initial advantages can influence long-run patterns of production and trade. My main results show that initial input price advantages can have a long-run impact on the spatial distribution of production and trade patterns. Due to lower input costs, British shipbuilders were able to take an early lead in metal ship construction, overcoming the dominant position that North American producers held in the shipbuilding industry in the first half of the 19th century. Despite losing this advantage in the 1890s, British producers were able to maintain their dominant position in metal shipbuilding into the 20th century, while North American firms that were exposed to competition from British producers struggled to make the transition from wood to metal and went into decline.

A natural explanation for this pattern is that the industry was characterized by some sort of dynamic learning effects. My analysis of Navy shipyards indicates that in fact shipbuilding was characterized by learning spillovers, and that these were highly localized in nature. Such learning spillovers can explain how a temporary input cost advantage generated a persistent lead, as well as why successful metal shipyards tended to be clustered in just a few locations. Finally, a review of historical evidence suggests that the development of pools of skilled shipyard workers was likely to have been a key channel through which these localized learning effects operated.

One implication of this study is that interventions that allow one location to gain an early lead in an industry characterized by learning effects may have long-term benefits. While this suggests that industrial policy may be successful in certain cases, my findings also highlight the limits of such policies. Despite having access to a completely protected coastal market and a variety of other supporting policies there is no evidence that U.S. Atlantic Coast shipbuilders were able to eventually compete with the British on the international market. The most likely explanation here is that the timing of intervention is crucial. An initial advantage may help a country establish a dominant position in a new industry, but industrial policy may be less useful once producers in another country are already established.

It is interesting to note that after WWII, Japan, Korea and China all became internationally competitive shipbuilders with the help of temporary government aid (see, e.g., Lane (2016) on Korea). In future work it will be interesting to consider why shipbuilders in these countries were successful in markets where, even after decades of protection, U.S. shipbuilders were not. One potential explanation for this difference is that the changing nature of the shipping industry, including the changes in ship size and design induced by containerization, fundamentally altered the ship production process in ways that reduced the importance of craft skills.

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A Appendix

A.1 Example Lloyd's register page

Figure 8 provides an example of the data from the first page of the Lloyd's Register for 1871-72. We can see that the first ship on this list, the A.D. Gilbert, was a schooner (Sr) of 177 tons built in Truro (UK) by the Hodge shipyard in 1865. The details below the name indicate that this was a wood ship. The third entry, the A. Lopez, was a screw steamer (ScwStr) and below the name we can see that this ship was made of iron. For cost reasons, I have digitized only a subset of the information shown in the register in Figure 8: the ship name, type and construction details (shown in the "Ships" column), the tonnage, and information on the location of construction, shipyard, and year of launch (shown in the "Build" column).

Figure 8: Example of raw data from Lloyd's Register for 1871-72

1871–72. **A**

No.	Ships.	Masters.	Tons.	Dimensions. Length.	Breadth.	Depth.	Build. Where.	When.	Owners.	Port belonging to.	Port of Survey and Destined Voyage.	Years Assigned.	Character for Hull and Stores, also Date of Last Survey.
1	A. D. Gilbert Sr YM.69ovrpt1.B.	WHodgejr	177	108·0	23·5	12·5	Truro *Hodge*	1865 10mo.	W.F.Hodge	Truro	Lon.W.Inds. (A.&C.P.)	12	A 1 2,69
2	A. Hastings Sr I.B.	W.Donald *Salted*	81	86·2	21·4	8·8	N.Brns *M'Lelin*	1856	R.Jackson	Belfast	Bel. Coaster Rest.Bel.71–	— 6	A 1 3,71
✠3	A. Lopez ScwStm (Iron)MC.65	Villevarde 400HP.	1969 1371	282·0	38·5	26·1	Dmbtn *DennyB.*	1865 11mo.	Lopez&Co.	Alicante *4Blk Hds*	Cly.Alicante (A.&C.P.)	—	•A 1 1,66

A.2 Description of the Register data

Table 6 presents some basic statistics for the decades 1871-1880 and 1901-1910. The latter is the main focus of the analysis while the former provides a useful benchmark that falls after the disruptions cause by the U.S. Civil War but before substantial convergence in input prices had taken place.

Table 6: Summary of tonnage and active locations in 1871-80 and 1901-10

Country	Region	Material	Tons		Active locations	
			1870	1900	1870	1900
U.S.	Atlantic	Metal	102,243	1,216,970	8	21
U.S.	Atlantic	Wood	644,837	478,305	212	68
U.S.	Lakes	Metal	194	2,332,268	1	12
U.S.	Lakes	Wood	1,036	6,387	5	11
Canada	Atlantic	Metal	2,303	5,861	3	6
Canada	Atlantic	Wood	610,911	72,283	260	57
Canada	Lakes	Metal	0	84,427	0	4
Canada	Lakes	Wood	1,878	3,996	5	7

Table 7 describes the number of observations from each register divided into the U.S., Canada, U.K. and other locations. The data from the 1871 register cover the years 1850-1870, the 1889 register data cover 1871-1887, and the 1912 data are used for years 1888-1911. Note that the data in Table 7 do not include thousands of other entries from these registers that fall outside of the windows covered by each one. For example, the 1871 registers contain over 2,000 ships built before 1850 that are not included in the tallies.

It is worth noting that there appear to be some entries in, say, the 1912 registers for years before 1889 that are not included in the 1889 register. Thus, in principal the additional data in the 1912 registers could be used to fill in some missing observations for the period before 1889. However, doing so raises the possibility of generating duplicate entries, particularly because ship names change over time. Because of this possibility I have chosen not to use the 1912 data to augment the set of observations for the years before 1889.

Table 7: Number of vessels in each Register used in this project

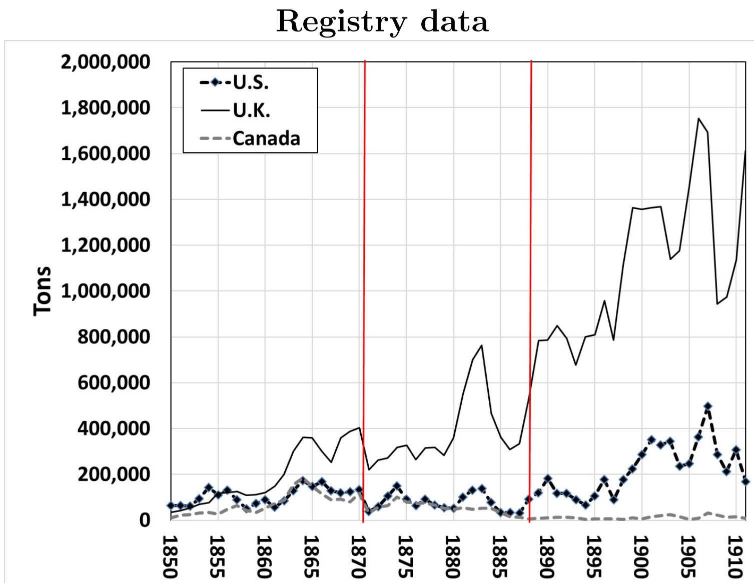
Year	Register	Total number of ships	No. vessels by location of build: U.S.	Canada	U.K.	Others
1871	Lloyd's	8,521	100	1,086	6,879	456
	ABS	12,185	5,594	2,547	1,502	2,542
1889	Lloyd's	8,620	11	278	7,429	902
	ABS	8,478	3,326	2,052	548	2,552
1912	Lloyd's	23,482	2,485	581	12,893	7,524
	ABS	8,164	3,418	331	3,464	951

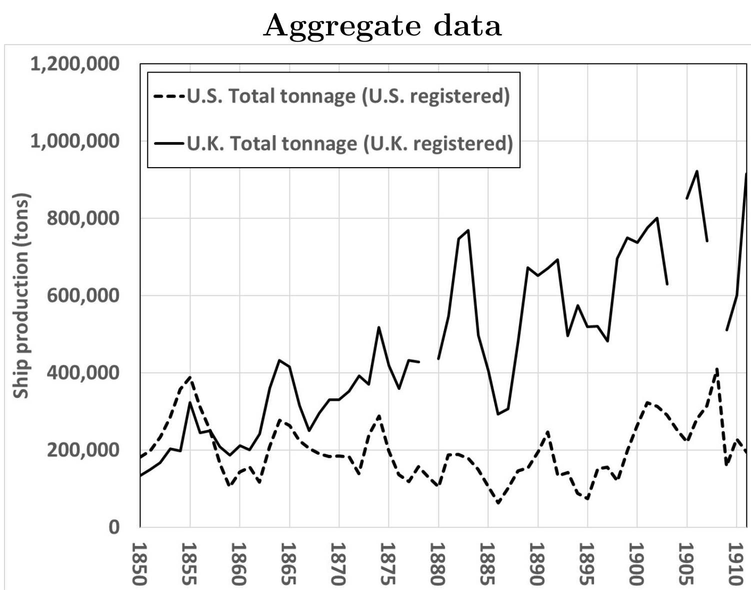
The counts from the 1871 registers include entries for ships built from 1850-1870. The 1889 register entries include ships built from 1871-1887. The 1912 entries include ships built from 1888-1911.

A.3 Aggregate tonnage data from alternative sources

This section presents data allowing me to compare the production figures obtained from my registry data to production figures based on existing aggregate data sources. Figure 9 presents overall production based on the Registry data used in the main text in the top panel and production based on existing aggregate data sources in the bottom panel. Note that the actual tonnage values are not strictly comparable across these series. There are several reasons for this. First, aggregate statistics generally cut off ships below a certain tonnage level, but they are often not explicit about exactly what the cutoff is. Some types of ships, such as barges, may also be excluded from the aggregate series but included in the registry data. Second, many of the available aggregate statistics include only vessels that were both produced in a country and then subsequently registered in that country. Third, there are often differences in the type of tonnage measure between the registers and the aggregate statistics. In general, the registers used a measure called net tonnage, while many aggregate statistics, particularly for the U.S., use gross tonnage. Unfortunately, the relationship between gross and net tonnage is different for each vessel, so there is no way to easily translate between them. For a further discussion of tonnage measurement issues see Appendix A in Pollard & Robertson (1979). Fourth, some vessels included in the aggregate data may be missed by the registry data. Despite these issues, the overall patterns observed in the two series are quite comparable. For example, both data series show total tonnage in the U.K. surpassing output in the U.S in 1857. Other patterns, such as the depression in 1886-87 and the spike in output in 1906-07 also look fairly similar. This provides some confidence that the Register data are doing a good job of capturing industry production.

Figure 9: Merchant shipbuilding in the U.S. and U.K., 1850-1913



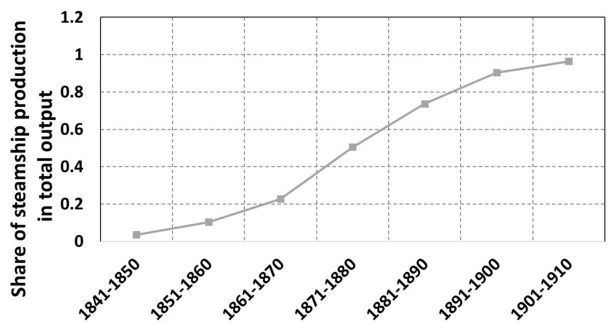


Notes: Data in the top panel come from the registries used in the main text. The bottom panel presents aggregate data for U.K. shipbuilding registered in the U.K., in net tons, from Mitchell & Deane (1962) and data for the U.S. from Hutchins (1948). The U.S. data have been converted from gross to net tons using a ratio of 1.5 gross tons to net ton which is derived by comparing U.K. output in gross tons and net tons using data from 1878-1911.

A.4 Evidence on the shift from sail to steam

Figure 10 describes the share of steamships in total ship output (by tonnage) in the U.S., U.K., and Canada, across the study period. Steam powered ship tonnage was almost insignificant prior to 1850, rose above 50% of total production in the 1880s, and was dominant after 1900. This transition from sail to steam was driven largely by improvements in engine efficiency (Pascali, 2017).

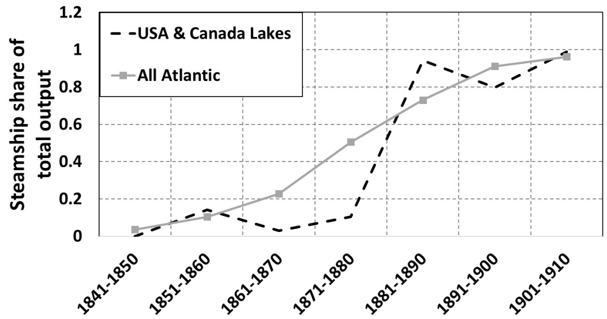
Figure 10: Share of steamship production



Next, Figure 11 compares the transition from sail to steam in the Great Lakes to the transition that took place in the Atlantic market (defined as the U.K. and Atlantic coast production the U.S. and Canada). We can see that the Great Lakes lagged behind in the use of steamships until after 1880 and then experienced a decade of rapid catch-up in the 1880s before settling to levels that were similar to those observed in the Atlantic market as a whole after 1890. After the 1890s the pattern of steamship construction in the Great Lakes looked very similar to the pattern observed in the Atlantic market.

It is important in Figure 11 that we compare the Great Lakes to the Atlantic market as a whole, rather than just North American producers on the Atlantic Coast. This is because the fact that North American Coastal producers remained concentrated on wood ship production also meant that they produced fewer steamships, where wood construction was a disadvantage.

Figure 11: Share of steamship production in the Lakes vs. the Atlantic



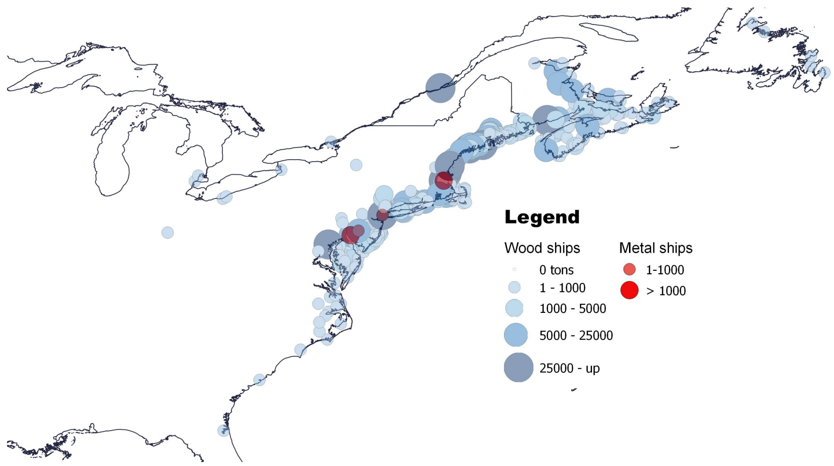
A.5 Maps of ship production

Figure 12 maps the distribution of production of wood and metal ships in the decades 1871-1880 and 1901-1910. These maps bring us closer to the approach used in the econometric analysis, which studies patterns at the level of individual shipbuilding locations. I consider these two periods because the first falls after the U.S. Civil War but before the elimination of the differences in input prices between the U.S. and Britain, while the second period falls after the input price differences had disappeared. These maps illustrate the strong shift in North American ship production from the Atlantic Coast to the Great Lakes, and the shift from wood to metal ships. It is clear that the shift from wood to metal was more extensive in the Great Lakes than on the Atlantic Coast, despite the preferential access of Great Lakes shipbuilders to timber resources.

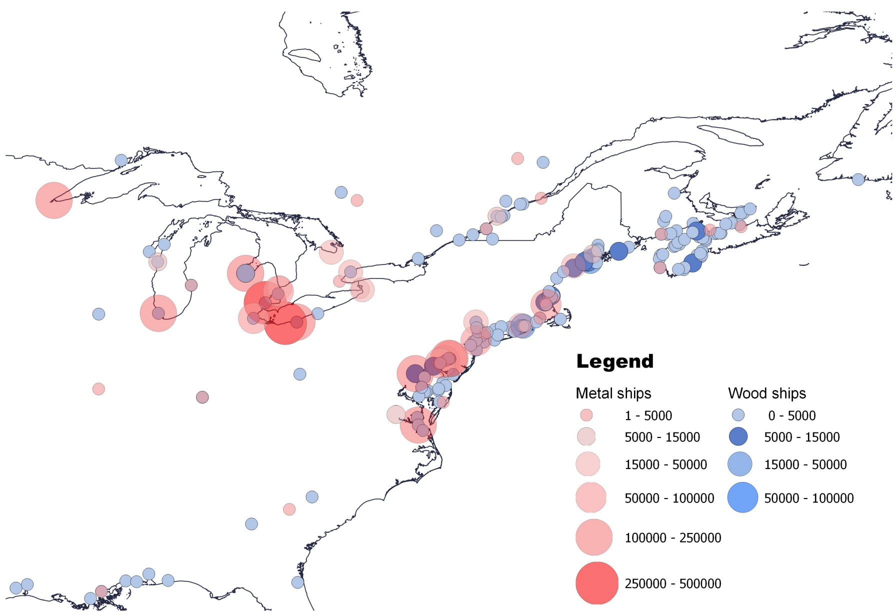
Figure 12 shows that on the Atlantic Coast metal ship production was mainly concentrated in a few locations: Boston, New York, along the Delaware River (Philadelphia, Camden, Wilmington, and Chester), Baltimore, and Newport News, Virginia. Notably, each of these locations was also close to one of the Navy shipyards established in the early 19th century, with the exception of Baltimore (where a Coast Guard shipyard was established in 1899).

Figure 12: Ship production in the U.S. and Canada, 1871-80 and 1901-10

1871-1880



1901-1910



Next, Figure 13 describes the shipyards included in the main analysis, with yards that were active after 1900 in black and all other yards in red.

Figure 13: Locations included in the main analysis

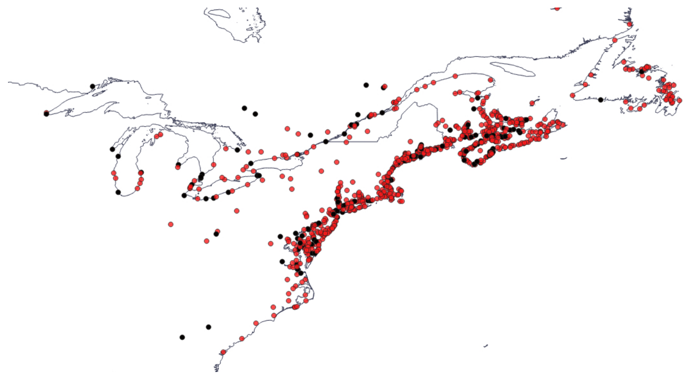
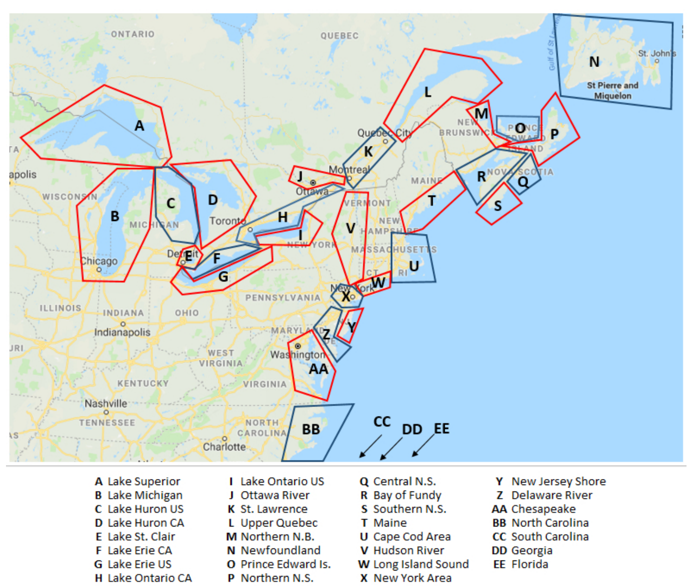


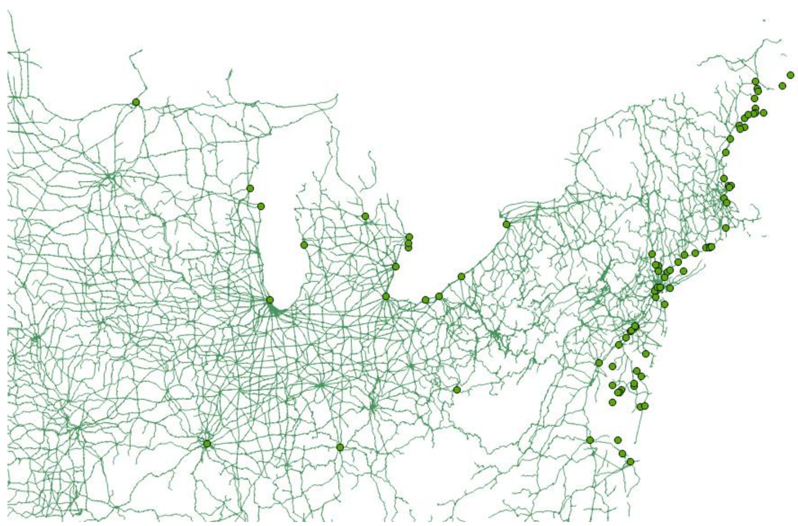
Figure 14 presents a map of the study regions with the various shipbuilding areas indicated. These are the areas used when standard errors are clustered on area (those in square brackets in the analysis tables). These areas reflect the delineation of the main shipbuilding regions during the study period.

Figure 14: Map of shipbuilding areas



It is also useful to look at how these production locations compare to existing transportation infrastructure. Naturally, all of the shipyards I study had access to water transportation. However, we may worry that some locations may not have had adequate access to railroad connections. This relationship is easiest to assess in the U.S., where detailed shapefiles of railroad location have been constructed by Jeremy Atack (2016). Figure 15 compares the location of railroads constructed before 1890 to the location of shipyards active in the U.S. from 1901-1910. This figure makes it clear that almost all shipyard locations had railroad connections by 1890. This should not be surprising given that a focus on the most developed regions of the U.S. in a period after most of the U.S. railroad system had been completed.

Figure 15: Shipyards and railroad locations in the U.S.



Railroad data are from Atack (2016) and include only lines constructed before 1890. Shipyard locations include all locations active between 1901 and 1910.

A.6 Maximum tonnage data

This appendix provides additional data on the maximum size of ships being produced in a particular market, period, or ship type. As a starting point, Figure 16 describes the evolution of maximum ship tonnage over time across markets and ship types for the U.S., U.K. and Canada. In all periods the largest ship was metal and constructed in the U.K. with the exception of 1841-1850, when the largest ship was made of wood and constructed in the U.S. Over the study period maximum ship size increased dramatically, from under 3,000 tons in 1841-1850 to over 30,000 tons after 1900. The unusual jump in maximum ship size in 1851-1860 was due to the construction of the *Great Eastern*, a massive one-off metal ship built in London with a size that was unsurpassed until 1899.

Figure 16: Evolution of maximum ship size over time

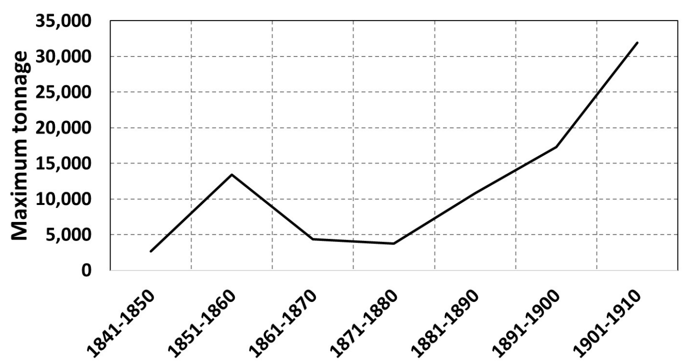
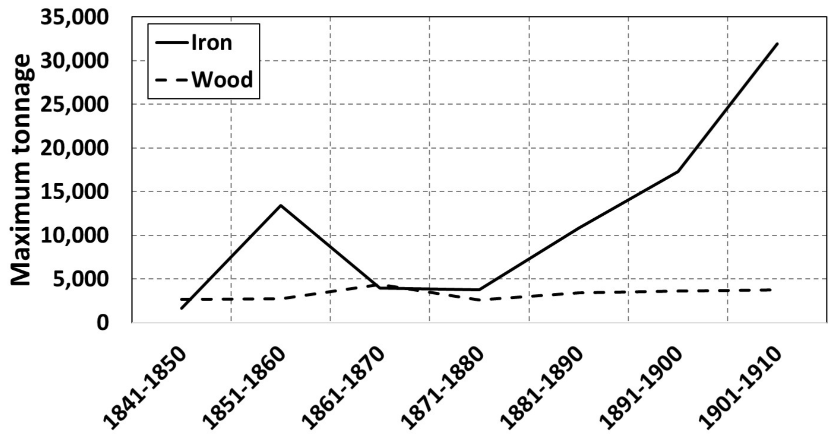


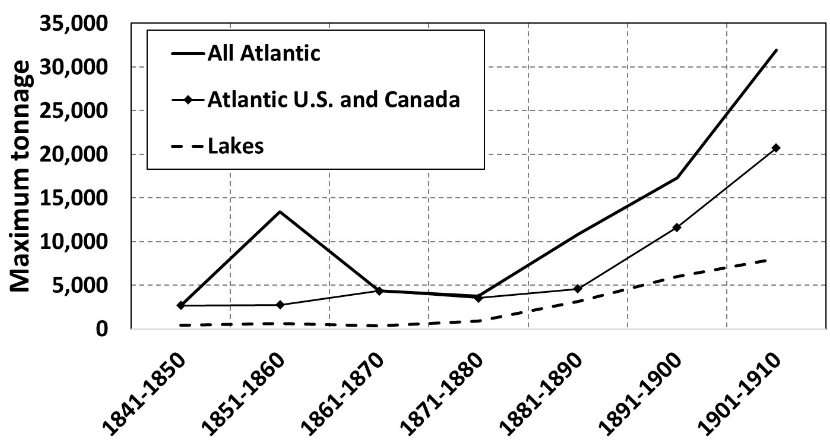
Figure 17 describes the largest ship produced in each period by type of construction (wood vs. metal). This graph makes it clear that the size of wood and metal ships was similar through 1880 (with the exception of the *Great Eastern* in 1851-60) but diverged substantially after that point, with metal ships growing much larger. In the end the size of wooden ships was constrained below about 4,300 tons across the entire study period and grew very little from 1850-1910. This illustrates the advantage that metal afforded in the construction of larger ships.

Figure 17: Evolution of maximum ship size by type of construction



Finally, Figure 18 describes maximum tonnage on the Atlantic Coast and the Great Lakes. We can see that maximum ship size grew in all locations, but less so on the Great Lakes. This was most likely a result of the limitation placed on lake ships by the size of canals. Overall, this suggests that, if anything, ship size should have generated stronger incentives for metal construction on the coast than on the lakes.

Figure 18: Evolution of maximum ship size on the Coast vs. the Lakes

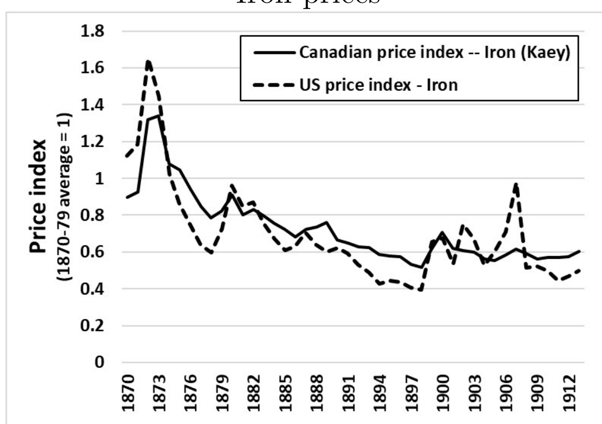


A.7 Comparing Canadian and U.S. input price trends

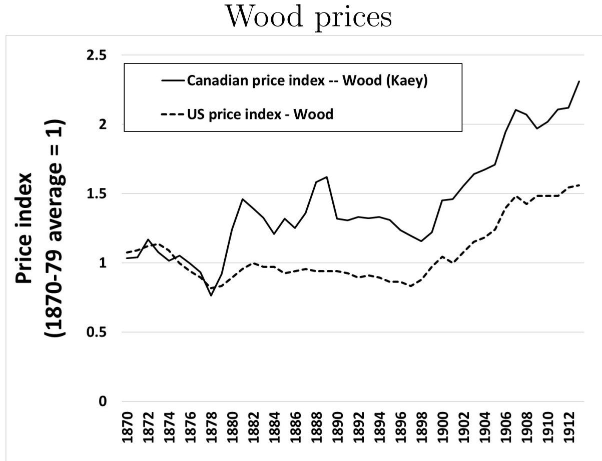
Figure 19 plots data describing the evolution of iron prices (top panel) and wood prices (bottom panel) in Canada compared to the U.S. starting in the 1870s. Because the Canadian price series are only available as an index, I convert the U.S. pig iron price series used in Figure 1 to an index. For both indices, I set the prices from 1870-1879 to equal one.[57] These data show the similarity between Canadian and U.S. input price trends.

Figure 19: Iron and wood price trends in Canada and the U.S.

Iron prices



Wood prices



Notes: U.S. prices are from Historical Statistics of the United States, Colonial Times to 1870, Vol. 1. I am grateful to Ian Kaey for sharing his Canadian price series with me.

[57] I use a full decade here to deal with the high level of price volatility in the 1870s, which means that the picture can change substantially when using only a single base year.

A.8 Description of county employment controls

The analysis includes controls for county-level employment in metal industries and lumber mills. These controls are constructed from the 1880 U.S. Census and 1880 Canadian Census records. I focus on 1880 primarily for data reasons, since I have not found county-level information on industry employment for the U.S. for 1890 or 1900. Using 1880 data also has the advantage of reducing endogeneity concerns, which may be an issue for controls based on data for 1900. The U.S. Census data were collected by Martin Rotemberg and Richard Hornbeck. The Canadian census data were entered from the original manuscripts.

I have tried to produce series that are consistent across the two countries. I focus on employment rather than output to avoid having to deal with exchange rates. For the U.S., the control for employment in metal industries includes: blacksmithing, brassware, bronzeware, copperware, cutlery and edge tools, fire-arms, hardware, iron and steel machinery, leadware, other machinery, other brass, bronze and copper products, saws, and steam fittings and heating apparatus. For Canada I include the following sectors: blacksmithing, metal founding and machinery production, edge tools, boilermaking, engine production, firearms, and saws. To control for wood employment, the U.S. series is "lumber and timber products" while the Canadian series is "saw mills."

County employment data is not reported for Newfoundland or some locations in the northern part of Quebec. Thus, a few observations are lost when these controls are included.

A.9 Input price data description

This section describes the sources of the input price data presented in Table 1. These data were gathered from the special industry reports included in Section 3 of the U.S. Census of Manufactures reports from 1900. Below I describe how these data series were constructed.

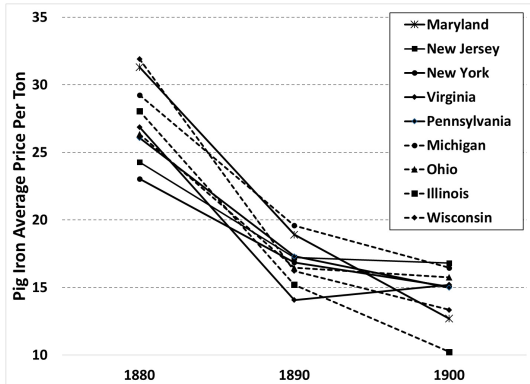
Pig iron price data

Pig iron price data at the state level were reported on p. 33-34 of the report for that industry. While some price information is available for other iron and steel products, including products such as metal plates that were particularly important for the shipbuilding industry, I focus on pig iron prices for three reasons. First, pig iron was a relatively homogeneous product (compared to more specialized metal products) that was widely produced. This improves the comparability of price data across locations. Second, pig iron was a key input into more specialized metal products used in shipbuilding. Third, pig iron was used as an input into a wide variety of goods. This reduces the chance that local prices could be endogenously affected by the local shipbuilding industry, which may be a concern when focusing on more specialized products where a large fraction of output was used by shipbuilders. It is worth noting that the 1900 Census report indicates that the price in Illinois is an outlier in being lower than the others because most pig iron used in that state was then used by the same companies as an input into steel production.

In addition to providing prices for 1900, the report also provided data for 1890 and 1880. Figure 20 graphs these prices by state, with the solid lines corresponding to states bordering the Atlantic and the dotted lines used for states in the Great Lakes (note that New York and Philadelphia border both the Atlantic and the Lakes). We can see that iron prices fell across all of the states in the sample. In 1880, iron prices were generally higher in the Great Lakes states, but prices fell more rapidly in the Lakes, so that by 1900 there was no systematic difference between iron prices in the Great Lakes states and prices on the Atlantic Coast.

Because the iron prices are only available for a subset of the states used in the analysis, I use information from nearby states in order to expand the set of locations that can be analyzed when including iron prices as a control. Specifically, I use the iron price from New York as the price for Connecticut and Rhode Island, the price from Virginia is used for North Carolina, the price from Maryland is used for Delaware and the District of Columbia, and the price from Georgia for South Carolina. The remaining U.S. states that are included in the main analysis but dropped when the iron prices control is included are Massachusetts, Maine, New Hampshire, and Florida.

Figure 20: Evolution of iron prices by state, 1880-1900



Lumber price data

The lumber price data are also drawn from the Census of 1900. These data are more complicated to prepare than the iron price data because different types of trees grow in different areas and these varieties have different quality levels. To begin, I collected data from a set of the most important types of lumber for shipbuilding: oak, pine, ash, white pine, spruce, poplar, and hemlock. These prices come from the special report on lumber and were provided by lumber producers, rather than users. All of these wood types are produced by multiple states and overlap with other types, but no type is produced everywhere, and I only observe the price of a variety in a location in which it was produced. The data I collect span 47 states (all of the lower 48 states except North Dakota).

These varieties differ substantially in price. For example, oak is systematically more expensive while pine tends to be less expensive. It is reasonable to expect that wood shipbuilders in a particular location built primarily using the type of wood that was more readily available near them.

To build a consistent index of wood prices, I run the following regression,

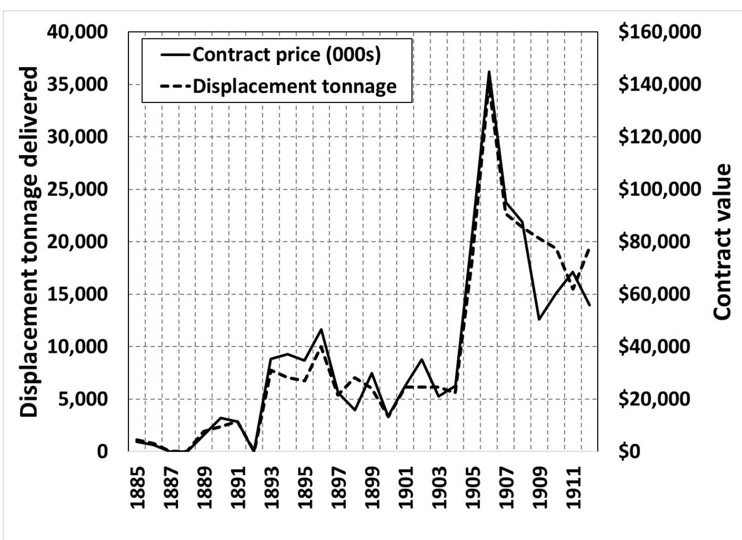
$$P_{is} = \alpha + \phi_i + \theta_s + \epsilon_{is}$$

where P_{is} is the price of lumber of type i in state s, ϕ_i is a full set of fixed effects for type-i lumber and θ_s is a full set of fixed state effects. I run this regression on all of the states for which price data are available for the varieties listed above. However, to reduce noise I drop the price for any state-type cell where less than one million board feet were produced because, with such a low level of production, prices in these cells tend to be noisy. Also, in my preferred approach I weight the regressions by the amount of production in each cell. Using this approach, I extract the state fixed effects θ_s which are used as my index of lumber prices. This approach generates price indices for all of the states included in my analysis (with Washington D.C. assigned the price for Maryland).

A.10 U.S. Naval shipbuilding

Figure 21 plots the tonnage of U.S. Navy ships produced (displacement tons) and the contract values across the New Navy period, according to the date of delivery. We can see that there were large increases in both tonnage and spending in the early 1890s and a second large increase starting in 1905.

Figure 21: U.S. Naval shipbuilding

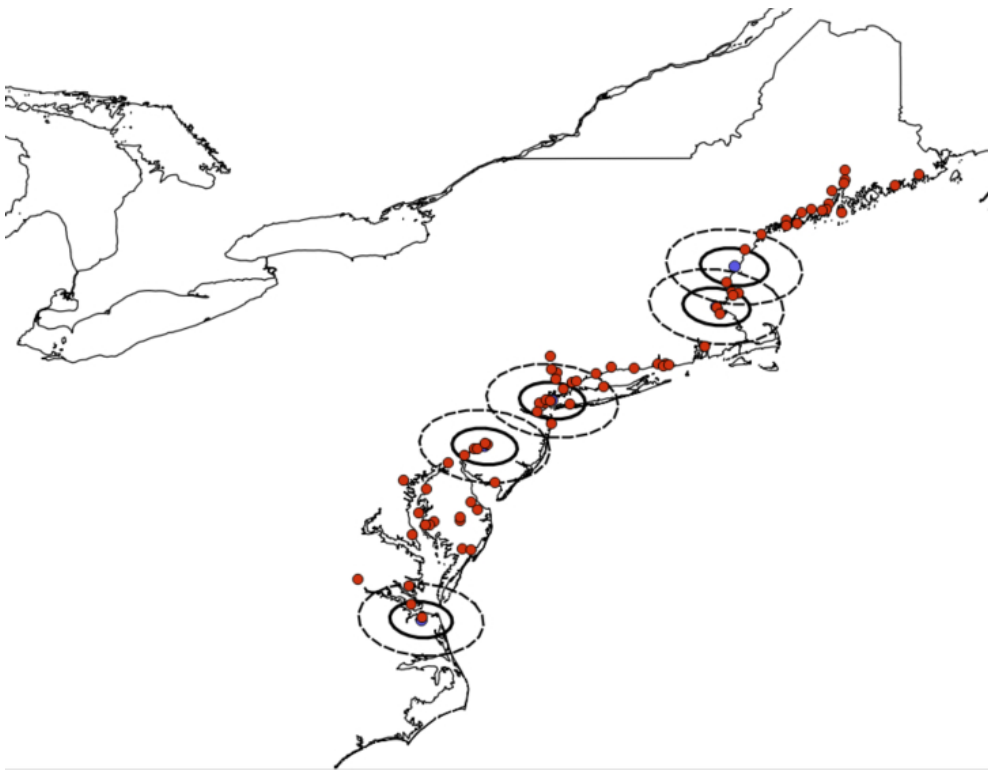


Data from Smith & Brown (1948).

A.11 Location of U.S. Navy Shipyards

Figure 22 plots the location of U.S. Navy shipyards, with 50km rings (solid line) and 100km rings (dotted line) around each, together with the locations of each of the Atlantic Coast shipyards active in the 1901-1910 period.

Figure 22: Map of the location of U.S. Navy Shipyards



A.12 Data comparing homeport and construction locations

Table 8 uses information on the homeport of ships entered from the 1912 ABS Register in order to compare construction locations and location of use. The key take-away from this table is that the vast majority – 96.9% – of ships homeported in the Great Lakes were also constructed in the Great Lakes. Also, British ships accounted for only 1.3% of the Great Lakes tonnage registered in the ABS. In contrast, only about 82.2% of the tonnage homeported on the Atlantic Coast of the U.S. and Canada was also constructed there, while British producers captured almost 10% of the market. Overall, these figures suggest that the Great Lakes market was much more isolated from outside competition than the Atlantic Coast market.

Table 8: Tonnage by construction location and homeport location

Location of construction		**Homeport Location**			
		Atlantic		Great Lakes	
Country	Region	Tons	Share	Tons	Share
US	Atlantic	1,664,017	0.791	44,667	0.018
	Great Lakes	113,749	0.054	2,347,871	0.950
	Other	54,233	0.026	1,256	0.001
Canada	Atlantic	65,987	0.031	0	0.000
	Great Lakes	1,801	0.001	45,931	0.019
UK		201,534	0.096	31,531	0.013
Other foreign		2,067	0.001	0	0.000
Total		**2,103,388**		**2,471,256**	

All data are derived from the 1912 ABS data and cover the years 1890-1912.

Table 9 provides some evidence on the penetration of foreign shipbuilders into the U.S. and Canadian markets on the Atlantic Coast. We can see that U.K. producers built 7.6% of the tonnage homeported on the Atlantic Coast of the U.S., but 46% of tonnage on the coast of Canada. An additional 6% of Canadian Atlantic ship tonnage came from U.S. producers, while Canadian producer supplied less than 1% of U.S. tonnage. These figures reflect the important role that U.S. trade protections likely had on the use of foreign ships.

Table 9: Construction location for tonnage homeported on the Atlantic Coast of the U.S. and Canada

Country of Construction	Homeport Location			
	U.S.		Canada	
	Tons	Share	Tons	Share
US	1,825,175	0.915	6,824	0.062
Canada	15,619	0.008	52,169	0.476
UK	150,911	0.076	50,623	0.462
Other foreign	2,067	0.001	0	0.000
Total	**1,993,772**		**109,616**	

All data are derived from the 1912 ABS data and cover the years 1890-1912.

An alternative view of market segmentation is provided by Table 10, which looks at the homeport locations of vessels constructed in the Great Lakes or on the Atlantic Coast of the U.S. and Canada. We can see that 94.4% of the tonnage constructed on the Great Lakes is also homeported on the Great Lakes, in either the U.S. or Canada. In contrast, only 83.5% of the tonnage constructed on the Atlantic coast of the U.S. and Canada is also homeported there, while 8.6% of tonnage is homeported in a foreign country. Again, this highlights the much more closed nature of the Great Lakes market.

Table 10: Homeport locations for tonnage built in the Great Lakes or Atlantic Coast of the U.S. and Canada

Homeport location		Location of construction			
Country	Region	Atlantic		Great Lakes	
		Tons	Share	Tons	Share
US	Atlantic	1,676,726	0.809	109,835	0.043
	Great Lakes	10,144	0.005	2,339,580	0.922
	Other	119,083	0.057	18,885	0.007
Canada	Atlantic	53,278	0.026	5,715	0.002
	Great Lakes	34,523	0.017	54,222	0.021
UK		40,182	0.019	2,100	0.001
Other foreign		138,488	0.067	6,654	0.003
Total		**2,072,424**		**2,536,991**	

All data are derived from the 1912 ABS data and cover the years 1890-1912.

A.13 Examining ship drafts in different locations

One may worry that ships in the Great Lakes were different because they faced greater depth constraints and that this may have provided additional incentives for metal ship construction on the Lakes. This is because metal ships could typically carry more cargo for a given draft. To examine this issue I have entered the draft (depth) statistics for the first 1000 ships listed in the 1912 ABS. These data allow me to assess whether there appears to be differences in ship construction related to depth constraints in the Great Lakes. If depth constraints were important, then we may have expected Great Lakes producers to focus on different types of ships (e.g., metal instead of wood) but also to choose different designs within ship classes. It is not possible to assess the importance of depth constraints by looking along the first dimension, since the choice of metal vs. wood will also be affected by whether a location was protected from British competition. However, if depth constraints were important then we should also see some differences within ship types, as Great Lakes producers modified their designs to deal with these constraints. Thus, in this section I look for evidence that depth constraints mattered by looking at whether, within ship types, designs appear to differ in the Great Lakes in a way that reduces ship draft.

Table 11 presents results describing ship depths for ships built in the Great Lakes, on the North American Atlantic Coast, in the U.K., or in another foreign country. Panel A, which covers all ships, shows that on average ships in the Great Lakes were larger and deeper than ships constructed on the Atlantic Coast, but roughly comparable to ships constructed in the U.K. or other foreign locations. The fact that ships on the Great Lakes were, on average, deeper than those constructed on the Coast provides a first indication that depth constraints were not important on the lakes.

Panel B focuses only on metal ships, while in Panel C I include only large metal ships (over 1000 tons). Panel C is the most important here, because these large ships are where depth constraints are likely to be most important. They also make up a large fraction of total ship tonnage. We can see that among this group, ships on the Great Lakes were very similar to ships built in either the Atlantic Coast, the U.K., or other foreign countries, in terms of depth and average tonnage as well as the ratio of depth to gross tonnage. Thus, there does not appear to be any substantial design differences between the Great Lakes and other locations among the type of ships where depth constraints would have been the most important. Panels D and E present similar patterns for wood ships. Again, for the larger wood ships in Panel E, where depth constraints would have been most important, we see no substantial differences between the Great Lakes and the Coast or other foreign locations in terms of average depth or tonnage. If anything, it appears that ships on the Great Lakes drew more water per ton of displacement.

It is worth considering why, given the shallowness of the Welland Canal, which went around Niagara Falls, and the Lachine Canal at Montreal, that ships built on the Great Lakes don't seem to have differed in their design in a way that reduced draft. The answer is that the vast majority of ships on the Great Lakes were never intended to pass through either of these very small canals. Instead, cargo intended for the Atlantic market would typically be transferred to canal boats and sent to the coast through either the Erie Canal or the Welland and Lachine Canals, or to the railroad. This limitation is exactly why large ships constructed on the Great Lakes were trapped there, and why it was very hard to move large ships constructed elsewhere into the Great Lakes. However, given that a ship was not intended to pass through these locks, the other locks in the Great Lakes system, such as those between Lake Superior and Lake Huron at Sault Ste. Marie, or the channel at Detroit, did not impose depth constraints that were substantially different than those faced in many ports by ocean going vessels. For example, the Weitzel Lock (1881) linking Lake Superior and Lake Huron had a depth of 17 feet, which was expanded to 21 feet by the construction of the Poe Lock in 1896.

Evidence from (Brooks *et al.*, 2016, Fig. 2b) shows that U.S. ports operating with depths over 10 feet at mean low water were not at a disadvantage in the first half of the 20th century. Only with the introduction of containerization after 1950, and the resulting increase in ships size, does being near a deeper port begin to matter for local population growth. They explain this pattern by noting that, while port depth could pose a constraint for the largest ocean liners, the vast majority of commerce prior to containerization was carried on more moderately sized vessels that could access most port locations.

Table 11: Ship depth statistics by location of build and ship type

A. All ships	Atlantic Coast	Great Lakes	U.K.	Other Foreign
Average depth (ft)	13.92	20.71	24.39	22.12
Average tonnage	936	2,687	3,730	2,943
Avg. depth (ft) / 1000 tons	42.981	19.226	8.169	13.814
B. Iron and steel ships				
Average depth (ft)	15.90	23.46	24.43	23.80
Average tonnage	1,436	3,402	3,740	3,420
Avg. depth (ft) / 1000 tons	38.858	12.615	8.085	9.084
C. Iron and steel ships over 1000 tons				
Average depth (ft)	21.01	24.47	24.86	24.19
Average tonnage	3,228	3,654	3,868	3,518
Avg. depth (ft) / 1000 tons	8.405	8.328	7.527	8.813
D. Wood ships				
Average depth (ft)	12.67	14.37	n.a.	14.14
Average tonnage	625	1,039	n.a.	524
Avg. depth (ft) / 1000 tons	45.541	34.459	n.a.	37.756
E. Wood ships over 1000 tons				
Average depth (ft)	19.28	19.10	n.a.	20.10
Average tonnage	1,743	1,824	n.a.	1,201
Avg. depth (ft) / 1000 tons	12.868	19.105	n.a.	19.105

Data cover the first 1,000 ships (listed alphabetically on ship name) in the 1912 ABS.

A.14 Examining shipowners

This appendix uses a 10% sample of ship owners gathered from the 1912 ABS registry to study the structure of ship ownership in different regions. Specifically, ownership information was entered for every tenth page of the 1912 ABS and then cleaned and processed. The 1912 ABS register was chosen to match to the available homeport information. This provides a sample of the ownership structure for just over 800 ships active in 1912.

A good starting point for looking at the ownership structure is the HHI levels shown in Table 12. We can see that across all locations the ownership concentration was low. This was particularly true for more international markets, such as those served by U.K. shipbuilders, while concentration was higher (but still quite low) in the protected Great Lakes market.

Given these levels of concentration it seems unlikely that any one shipowner would have been able to exert substantial market power.

Table 12: Ownership concentration by region (HHI index values)

Region	By homeport region	By region of construction
Atlantic North America	503	306
Great Lakes	700	627
United Kingdom	155	93
Other Foreign		355

It is also interesting to look at the types of owners present in each region. Table 13 presents the top ten owners (by tonnage) of vessels homeported on the North American Atlantic Coast and in the Great Lakes. Note that this comes from just a 10% sample of the data, so these data should be taken as a general indicator of the types of owners present, rather than the actual share of individual owners. Given the low levels of concentration in the industry, some important shipowners may be omitted simply due to random chance.

The types of owners described in Table 13 can be divided into various types. One type of owner is the end-users, such as Standard Oil and U.S. Steel (owner of Pittsburgh Steamship Co. after 1901). There were also many independent transportation companies, such as the Pioneer Steamship Company and Picklands Mather on the Great Lakes, or American-Hawaiian and Arthur Sewall on the Coast. We also see some companies that were either owned by railroads or affiliated with railroad owners. Examples of this type include the Southern Pacific, Old Dominion and Pacific Mail Steamship Companies, all of which were associated with Collis Huntington's railroad empire. Overall, it appears that no particular owner type was dominant in either the Atlantic or the Great Lakes markets.

Table 13: Top owners by homeport region

Atlantic Coast		Great Lakes	
Owner	Share	Owner	Share
Standard Oil Co	0.1516751	Pittsburgh SS Co	0.221867
American Hawaiian SS Co	0.1217836	Pioneer SS Co	0.0693328
Reading Co	0.0429164	Gilchrist Trans. Co	0.0613465
Coastwise Trans. Co	0.0350205	Picklands Mather & Co	0.0473607
Old Dominion SS Co	0.0340853	William P Snyder	0.0305225
Southern Pacific Co.	0.033155	Shenango SS Co	0.0246188
Arthur Sewall & Co	0.0307496	Valley SS Co	0.0246188
US Government, Navy Dept.	0.0262762	Mutual SS Co	0.0235367
Pacific Mail SS Co	0.0243914	La Belle SS Co	0.0227313
Maine SS Co	0.0230369	Calumet Trans. Co	0.0224794

A.15 Additional results for whether a location was active

This section presents some additional results looking at the factors that predict whether a location was active in producing a particular type of ship (wood or metal) in the 1901-1910 period. The first table shows results that allow the production of sail vs. steam ships to be different choices. Thus, the outcome variable can take five values: 0 if the location was inactive; 1 if the location produced wood sailing ships; 2 if the location produced wood steamships; 3 if the location produced metal sailing ships; 4 if the location produced metal steamships. To keep things tractable, I treat these as independent decisions. This differs from the specification used in the main text, which considers the joint production of iron and wood ships to be a different choice than producing only iron.

One reason to consider this specification is that we may be concerned that differences in the use of steamships between the Great Lakes and Coastal regions may have contributed to differences in the use of metal vs. wood for construction. Looking at the effect of being in the Great Lakes on production of metal vs. wood ships within ship type can address this potential concern. However, because we are dividing the data into smaller cells we should expect this specification to deliver results with larger standard errors.

Table 14 presents ML regression results differentiating by both material of construction and power source. Note that these results do not include the specifications with controls for the iron and lumber prices. Doing so reduces the sample size and makes it difficult to estimate reliable results when using more categories.

In the top panel, we see that shipbuilders in the Great Lakes or in the U.S. were not more likely to be active in building wood sailing ships. In the second panel, we see evidence that both Great Lakes and U.S. shipbuilders were more likely to be active in the construction of wood steamships. In the third panel we see some evidence that Great Lakes producers were more likely to be active in metal sailing ship production, though with few ships falling into this category the results are not statistically significant. In the fourth panel, the results show that both the Great Lakes and U.S. locations were more likely to be active in metal steamship production. This result indicates that my main findings continue to hold when looking only within steamships. At the bottom I test for whether locations in the Great Lakes were more likely to be active in metal steamships than in wooden steamships. In general, this test suggests that they were, though the results weaken in Column 5 when the county-level controls are included. It is worth noting that these county-level controls have very little explanatory power, which suggests that the main reason that the results weaken somewhat in Column 5 may be the loss of observations.

The next set of results, in Table 15, treat the U.S. Great Lakes and Canadian Great Lakes regions separately. We can see that locations in the Great Lakes were more likely to be active in metal ship production in both the U.S. and Canada, though the coefficients are smaller for Canada and the smaller sample sizes driving each coefficient mean that the results are somewhat imprecise. The fact that the coefficients between the U.S. and Canada are not statistically distinguishable in my preferred specification in Column 3 motivates the pooling of these two areas in the main results.

Table 14: Multinomial logit regression results by ship material and power source

	(1)	(2)	(3)	(4)	(5)
A=1: Location active in wood sailing ships in 1901-1910					
U.S. Coastal	-0.757**	-0.703*	-0.740**	-0.782**	-0.267
	(0.273)	(0.278)	(0.283)	(0.299)	(0.620)
	[0.412]	[0.412]	[0.354]	[0.337]	[0.632]
Great Lakes	-1.775	-1.612	-1.443	-1.295	-1.327
	(1.025)	(1.038)	(1.028)	(1.034)	(1.057)
	[0.966]	[0.978]	[0.956]	[0.954]	[1.088]
A=2: Location active in wood steamships in 1901-1910					
U.S. Coastal	1.068**	1.156**	1.115**	1.393***	1.605**
	(0.372)	(0.377)	(0.382)	(0.395)	(0.613)
	[0.440]	[0.425]	[0.534]	[0.554]	[0.533]
Great Lakes	1.905***	2.186***	2.287***	2.105***	2.053***
	(0.489)	(0.528)	(0.500)	(0.509)	(0.588)
	[0.381]	[0.448]	[0.437]	[0.469]	[0.487]
A=3: Location active in metal sailing ships in 1901-1910					
U.S. Coastal	-0.757	-0.434	-0.682	-0.151	1.555
	(1.227)	(1.229)	(1.230)	(1.271)	(2.730)
	[1.069]	[1.128]	[1.085]	[0.877]	[1.514]
Great Lakes	-10.974	-11.594	-18.987	-25.407	-22.899
	(466)	(1473)	(30950)	(7.20e+05)	(50494)
	[0.653]	[0.751]	[0.584]	[0.665]	[2.318]
A=4: Location active in metal steamships in 1901-1910					
U.S. Coastal	1.547**	1.606**	1.525*	2.056**	1.086
	(0.554)	(0.599)	(0.676)	(0.719)	(0.867)
	[0.721]	[0.749]	[0.854]	[0.806]	[0.774]
Great Lakes	3.397***	3.912***	4.195***	3.905***	3.057***
	(0.583)	(0.677)	(0.693)	(0.719)	(0.808)
	[0.746]	[0.821]	[0.854]	[0.884]	[0.872]
Testing Lakes effect within steamships, i.e., A=4 different from A=2					
p-value	0.0392	0.0347	0.0184	0.0306	0.2878
Observations	833	833	833	833	780

*** p<0.01, ** p<0.05, * p<0.1 based on robust SEs, shown in parentheses. Standard errors in brackets are clustered on shipbuilding area. Column 2 includes controls for whether a location is active in shipbuilding in 1870. Column 3 includes as controls separate indicators for whether the location is active in metal or wood shipbuilding in 1870. Column 4 includes as controls separate variables for tonnage produced in metal steamships, metal sailing ships, wood steamships, or wood sailing ships in 1870. Column 5 includes the controls in Column 4 as well as separate controls for the tonnage of wood and metal ships produced within 100km of each location in 1870, log county population, and the share of metalworking and lumber milling in county employment. Reference category is the location is inactive in both metal and wood shipbuilding in 1901-1910. Data include all locations active in shipbuilding from 1840-1910 in in the Atlantic Coast or Great Lakes regions of the U.S. and Canada. Tests of coefficient differences use robust SEs.

Table 15: ML regression results separating Great Lakes into U.S. and Canada

	(1)	(2)	(3)
A=1: Location active in wood shipbuilding only in 1901-1910			
U.S. Coastal	-0.082	0.009	0.308
	(0.209)	(0.228)	(0.485)
	[0.379]	[0.402]	[0.543]
Great Lakes – U.S.	0.030	0.310	0.609
	(0.563)	(0.590)	(0.745)
	[0.396]	[0.412]	[0.665]
Great Lakes – Canada	0.582	0.850	0.501
	(0.491)	(0.516)	(0.569)
	[0.444]	[0.441]	[0.512]
A=2: Location active in metal shipbuilding only in 1901-1910			
U.S. Coastal	0.630	1.046	0.456
	(0.712)	(0.903)	(1.412)
	[0.834]	[0.820]	[1.127]
Great Lakes – U.S.	3.143***	1.756	1.541
	(0.763)	(0.909)	(1.492)
	[0.807]	[0.808]	[1.386]
Great Lakes – Canada	2.779**	1.568	1.261
	(0.850)	(0.977)	(1.117)
	[0.926]	[0.920]	[0.890]
A=3: Location active in both wood and metal shipbuilding in 1901-1910			
U.S. Coastal	1.546*	2.574**	2.372
	(0.637)	(0.840)	(1.576)
	[0.536]	[1.009]	[2.106]
Great Lakes – U.S.	3.480***	5.363***	5.152**
	(0.725)	(1.010)	(1.737)
	[0.542]	[1.041]	[2.342]
Great Lakes – Canada	1.681	3.295*	1.790
	(1.179)	(1.327)	(1.887)
	[0.711]	[1.086]	[2.102]
Controls:			
Activity in 1870		Yes	Yes
Nearby activity in 1870			Yes
County controls			Yes
Observations	833	833	779
Testing U.S. different from Canada for outcome A=2			
p-value	0.6467	0.8163	0.8722
Testing U.S. different from Canada for outcome A=3			
p-value	0.1063	0.0758	0.2009

*** p<0.01, ** p<0.05, * p<0.1 based on robust SEs, shown in parentheses. Standard errors in brackets are clustered on shipbuilding area. The analysis covers all locations active in shipbuilding from 1850-1910 in in the Atlantic Coast or Great Lakes regions of the U.S. and Canada. Column 2 includes controls for whether a location is active in metal or wood shipbuilding in 1870 as well as separate variables for tonnage produced in metal or wood in 1870. Column 3 adds additional controls for metal or wood shipbuilding at other locations within 100km, county log population, and county employment shares in metalworking industries or lumber mills. Note that the county data are not available for some locations. Tests of coefficient differences use robust SEs.

A.16 Additional tonnage results

This section provides some additional tonnage regression results. Table 16 presents tonnage regression results run in levels rather than logs. This addresses the possible concern that results in the log specification may be driven mainly by smaller locations with little impact on actual overall tonnage. Instead, the results in Table 16 show that running the regressions in levels generate similar results to those in logs.

Table 16: Tonnage regression results in levels

	Dep. var.: Log of tons in 1901-1910				
	(1)	(2)	(3)	(4)	(5)
Great Lakes x Metal	150,758***	126,277***	126,778***	120,751*	120,799*
	(47,700)	(45,690)	(47,830)	(62,279)	(64,055)
	[39,497]	[41,054]	[41,433]	[43,832]	[42,544]
U.S. x Metal	51,208***	42,039**	47,785**		
	(16,907)	(16,272)	(22,389)		
	[23,350]	[15,268]	[18,420]		
Metal indicator	Yes	Yes	Yes	Yes	Yes
U.S. indicator	Yes	Yes	Yes		
Great Lakes ind.	Yes	Yes	Yes	Yes	Yes
Activity in 1871		Yes	Yes	Yes	Yes
Tonnage in 1871		Yes	Yes	Yes	Yes
Nearby tons in 1871			Yes		
County controls			Yes		Yes
Input prices				Yes	Yes
Observations	186	186	182	82	82
R-squared	0.326	0.362	0.405	0.444	0.456

*** p<0.01, ** p<0.05, * p<0.1 based on SEs clustered by location, shown in parentheses. Standard errors in brackets are clustered on shipbuilding area. Regressions are run only on sector-locations that were active in 1901-1910. Column 2 includes controls for whether a location is active in metal or wood shipbuilding in 1870 as well as separate variables for tonnage produced in metal or wood in 1870. Column 3 adds additional controls for metal or wood shipbuilding at other locations within 100km, county log population, the county employment share in metalworking industries, and the employment share in lumber. Note that the county data are not available for some locations. Column 4 includes the controls in Column 2 together with the log price of pig iron and log lumber index price in the state. These are only available for a subset of U.S. states, so the number of observations drops substantially. Column 5 includes the controls in Column 4 together with controls for county log population, the county employment share in metalworking industries, and the employment share in lumber.

Table 17 presents the same set of regressions as Table 3 in the main text but displaying the coefficients for each of the control variables.

Table 17: Tonnage regression results displaying controls

	Dep. var.: Log of tons in 1901-1910				
	(1)	(2)	(3)	(4)	(5)
Great Lakes x Metal	5.174***	4.802***	4.703***	2.522***	2.547***
	(0.731)	(0.798)	(0.811)	(0.895)	(0.887)
	[0.775]	[0.752]	[0.738]	[0.691]	[0.729]
U.S. Coast x Metal	2.467***	2.204***	2.396***		
	(0.700)	(0.714)	(0.782)		
	[0.942]	[0.694]	[0.705]		
Metal indicator	-0.0814	0.545	0.921	5.225	5.637
	(0.444)	(0.646)	(0.687)	(7.921)	(7.960)
	[0.517]	[0.522]	[0.565]	[5.355]	[5.627]
U.S. Coastal	0.543*	0.497*	0.608*		
	(0.280)	(0.265)	(0.365)		
	[0.455]	[0.325]	[0.366]		
Great Lakes	-0.791**	-0.245	0.158	-0.319	-0.0813
	(0.312)	(0.329)	(0.388)	(0.558)	(0.551)
	[0.280]	[0.323]	[0.330]	[0.486]	[0.326]
Active in same sector-loc		0.942	0.984	1.700*	1.704*
in 1871-80		(0.671)	(0.680)	(0.910)	(0.937)
		[0.525]	[0.575]	[0.743]	[0.857]
Active location in 1871-80		-0.0758	-0.144	-0.992	-0.938
		(0.718)	(0.728)	(0.983)	(0.997)
		[0.611]	[0.646]	[0.832]	[0.956]
Tons in same sector-loc		0.290***	0.230**	-0.126	-0.256
in 1871-80		(0.0878)	(0.0892)	(0.430)	(0.503)
		[0.0896]	[0.0741]	[0.372]	[0.456]
Total tons in location		0.0472	0.0778	0.455	0.664
in 1871-80		(0.0704)	(0.0724)	(0.405)	(0.496)
		[0.0569]	[0.0575]	[0.452]	[0.560]
Tons in same sector within			-0.0682		
100km in 1871-80			(0.0649)		
			[0.0514]		
Total tons within			0.139**		
100km in 1871-80			(0.0621)		
			[0.0552]		
Log county pop.			-0.00194		-0.147
			(0.0619)		(0.143)
			[0.0362]		[0.137]
County metal emp. shr.			11.54		1,698
			(53.04)		(1,249)
			[54.40]		[700.5]
County lumber emp. shr.			4.054		31.31
			(9.326)		(253.5)
			[10.46]		[254.1]
Log iron price				-2.482	-3.289
				(2.361)	(2.157)
				[2.913]	[2.546]
Log lumber price				1.182	1.542
				(1.206)	(1.252)
				[1.218]	[1.321]
Log iron price x Metal				-2.085	-2.444
				(2.863)	(2.857)
				[3.441]	[3.539]
Log lumber price x Metal				1.693	1.917
				(2.358)	(2.202)
				[2.699]	[2.538]
Observations	186	186	182	82	82
R-squared	0.427	0.516	0.551	0.620	0.640

*** p<0.01, ** p<0.05, * p<0.1 based on SEs clustered by location, shown in parentheses. Standard errors in brackets are clustered on shipbuilding area. Regressions are run only on sector-locations that were active in 1901-1910.

In Table 18 I consider results looking at steam and sailing vessels separately. In Columns 1-2 I generate results looking only at steamships. There is clear evidence that metal steamship tonnage was larger in the more protected Great Lakes and U.S. markets. In Columns 3-4 I present results looking only at sailing ships. Here we see no evidence that there was greater metal tonnage in the Great Lakes or in the U.S. This shows that the tonnage results in the main text are driven entirely by steamships. Finally, Columns 5-6 include both types of ships and add triple interactions between the metal, steam power, and either the lakes or the U.S. market.

Table 18: Tonnage regression results separating sail and steamships

	Dep. var.: Log of tons in 1901-1910					
	Steamships only		**Sail only**		**Combined**	
	(1)	(2)	(3)	(4)	(5)	(6)
U.S. Coastal x Metal	3.320***	3.331***	-0.0942	-0.421	-0.203	-0.318
	(0.837)	(0.803)	(0.601)	(0.798)	(0.597)	(0.648)
	[0.968]	[0.608]	[0.603]	[0.778]	[0.604]	[0.523]
Great Lakes x Metal	4.978***	5.776***	0.496	0.992	0.387	0.274
	(0.885)	(0.808)	(0.545)	(1.063)	(0.541)	(0.607)
	[0.973]	[0.576]	[0.336]	[0.949]	[0.342]	[0.405]
Lakes × Metal × Steam					5.063***	5.357***
					(1.097)	(1.135)
					[1.013]	[0.803]
U.S. Coast × Metal × Steam					3.995***	3.722***
					(0.925)	(0.973)
					[0.902]	[0.715]
Metal indicator	0.335	-0.0227	0.231	-0.626	0.340	0.736**
	(0.651)	(0.595)	(0.218)	(0.627)	(0.208)	(0.310)
	[0.792]	[0.402]	[0.276]	[0.676]	[0.284]	[0.259]
U.S. Coast indicator	-0.0356	-0.289	1.225***	0.291	1.334***	0.951**
	(0.376)	(0.409)	(0.295)	(0.637)	(0.288)	(0.380)
	[0.220]	[0.361]	[0.369]	0.666]	[0.372]	[0.395]
Great Lakes indicator	-0.442	-0.178	0.108	-0.290	0.217	0.342
	(0.397)	(0.397)	(0.471)	(0.689)	(0.466)	(0.559)
	[0.269]	[0.301]	[0.478]	[0.693]	[0.479]	[0.570]
Metal × Steam					-0.477	-0.747
					(0.645)	(0.712)
					[0.738]	[0.568]
Lakes × Steam					-1.131**	-0.812
					(0.498)	(0.607)
					[0.463]	[0.584]
U.S. × Steam					-1.841***	-1.330***
					(0.277)	(0.335)
					[0.290]	[0.261]
Other controls		Yes		Yes		Yes
Observations	111	108	117	116	228	224
R-squared	0.640	0.747	0.165	0.289	0.510	0.595

*** p<0.01, ** p<0.05, * p<0.1 based on SEs clustered by location, shown in parentheses. Standard errors in brackets are clustered on shipbuilding area. Regressions are run only on sector-locations that were active in 1901-1910. Other controls include whether the location was active in a sector in the 1870s, whether the location was active at all in the 1870s, tonnage in the sector-location in the 1870s, tonnage in the location overall in the 1870s, log county population, county metalworking employment share and county lumber milling employment share.

Table 19 provides results for regressions run separately on the U.S. and Canada (looking at the effect of being in the Lakes) or run separately on the Lakes and Atlantic Coast (looking at the effect of being in the U.S.) using the log tonnage specification from Eq. 2. These results show that, conditional on being active in 1901-1910, locations in the Great Lakes produced more metal shipping in both the U.S. (Column 1) and Canada (Column 2). As we would expect, the importance of this protection was more important in Canada where coastal shipbuilders were more exposed to foreign competition. In Columns 3-4 we see that locations in the more protected U.S. market produced more metal ship tonnage on the Atlantic Coast while we see no clear evidence that being in the U.S. was associated with more production in the Great Lakes market.

Table 19: Separate tonnage regression results

	Dep. var.: Log of tons in 1901-1910			
	U.S. only	Canada only	Atlantic only	Lakes only
	(1)	(2)	(3)	(4)
Great Lakes x Metal indicator	3.093***	5.541***		
	(0.831)	(0.713)		
	[0.767]	[0.582]		
U.S. x Metal indicator			2.264***	1.207
			(0.698)	(0.988)
			[0.725]	[0.551]
Metal indicator	2.953***	-1.092*	0.409	4.766***
	(0.540)	(0.568)	(0.656)	(0.347)
	[0.503]	[0.540]	[0.573]	[0.202]
Great Lakes indicator	-0.792*	-0.374		
	(0.430)	(0.422)		
	[0.402]	[0.294]		
U.S. indicator			0.732	1.065
			(0.580)	(1.029)
			[0.647]	[1.053]
Active in the same sector-loc in 1871-80	1.451*	-1.098	0.759	-1.701
	(0.852)	(0.685)	(0.798)	(1.385)
	[0.583]	[0.668]	[0.673]	[1.473]
Active shipbuilding location in 1871-80	-0.397	1.654***	0.0987	1.683**
	(0.917)	(0.525)	(0.867)	(0.629)
	[0.683]	[0.498]	[0.777]	[0.431]
Tons in the same sector-location in 1871-80	0.323***	-0.133	0.294***	164.1***
	(0.103)	(0.136)	(0.0896)	(12.11)
	[0.0903]	[0.0725]	[0.0880]	[10.30]
Total tons in the location in 1871-80	0.0963	0.204*	0.0473	-147.3***
	(0.0774)	(0.108)	(0.0675)	(4.498)
	[0.0451]	[0.0816]	[0.0502]	[5.489]
Log county pop.	-0.0128	-0.175	-0.0306	-0.0484
	(0.0858)	(0.226)	(0.0912)	(0.0718)
	[0.0516]	[0.252]	[0.0530]	[0.0867]
County metal emp. shr.	736.9	24.75	22.06	88.70*
	(896.8)	(52.30)	(83.94)	(50.30)
	[562.8]	[62.62]	[98.25]	[58.94]
County lumber emp. shr.	314.7	5.707	2.419	25.47
	(199.8)	(10.26)	(12.92)	(18.67)
	[203.7]	[9.379]	[13.45]	[18.20]
Observations	112	70	150	32
R-squared	0.554	0.395	0.369	0.844

*** $p<0.01$, ** $p<0.05$, * $p<0.1$ based on SEs clustered by location, shown in parentheses. Standard errors in brackets are clustered on shipbuilding area. Regressions are run only on sector-locations that were active in 1901-1910.

A.17 Comparing Maine/Nova Scotia/New Brunswick

Table 20 provides some basic statistics comparing Maine to Nova Scotia and New Brunswick for 1880, just before the take-off of metal shipbuilding in North America began. From the table we can see that Maine had a larger population that either Nova Scotia or New Brunswick but that together the Canadian provinces had a slightly larger population. In terms of population density, Maine and Nova Scotia were very similar, while New Brunswick was less densely populated due to its large lightly inhabited inland areas.

Shipbuilding was an important industry in all three areas. In terms of either output or capital, the industry in Nova Scotia and New Brunswick together was similar in size to the industry in Maine. Because most of the shipbuilding in New Brunswick was clustered near some of the main shipbuilding areas of Nova Scotia in the Bay of Fundy, it is reasonable to consider these two provinces together. Shipbuilding accounted for around 2% of paid in manufacturing capital in Maine, around 3% in New Brunswick, and 5% in Nova Scotia.

The next set of statistics focus on the key inputs to shipbuilding, lumber and iron & steel. Lumber was an important industry in all three areas, though it was more important in New Brunswick than the others. In Maine and Nova Scotia, lumber firms represented a similar share of overall manufacturing capital, but the share was much higher, 35%, in New Brunswick. Local iron & steel manufacturing was present only in Maine and Nova Scotia, but the industry was substantially larger in terms of either output or capital in Nova Scotia. If anything, from these statistics we might expect that Nova Scotia had an advantage in metal ship production relative to Maine at the time when metal shipbuilding was emerging in North America.

Table 20: Basic statistics on Maine, Nova Scotia and New Brunswick

	Maine	Nova Scotia	New Brunswick	NS/NB Combined
Population:				
Total	648,963	440,572	321,233	761,805
Density (per sq. mi)	21.7	21.1	11.8	15.8
Shipbuilding:				
Output value	2,909,846	1,755,330	722,132	2,477,462
Capital	811,750	527,196	224,970	752,166
Shr of manuf. capital	0.02	0.05	0.03	0.04
Lumber:				
Output value	7,933,868	3,094,137	6,532,826	9,626,963
Capital	6,339,396	1,640,487	2,987,860	4,628,347
Shr of manuf. capital	0.13	0.16	0.35	0.25
Iron & Steel:				
Output value	583,328	720,000	0	720,000
Capital	450,000	1,850,000	0	1,850,000
Shr of manuf. capital	0.01	0.18	0.00	0.10

All output and capital values are in U.S. dollars, but the U.S. and Canadian dollars traded at par during this period.

A.18 Additional results for Navy shipyards

This appendix presents some additional robustness results looking at the impact of proximity to Navy shipyards on metal ship construction. Table 21 presents a variety of robustness checks using the log specification used in the main text. Column 1 conducts the same analysis as in the main text, but using only locations that were active in wood shipbuilding in 1870. This helps address the possibility that the Navy shipyard results may be due in part to selection.

Column 2 adds in an indicator for whether the location received Navy contracts using data from Smith & Brown (1948). The Navy contracts variable is probably a bad control such that the coefficient on Navy shipyards estimated in Column 2 is biased downwards. One reason to think this is that there is evidence that shipyards that received Navy contracts first had to show success in metal merchant ship construction. For example, an analysis of the hull list of ships built at Newport News shows that the shipyard began by producing metal merchant ships for the protected coastal market before later obtaining Navy contracts. The fact that, despite this concern, I still observe a statistically and economically significant impact of Navy shipyards on metal production in nearby private yards provides confidence that the spillover effects I document are not being driven simply by access to Navy contracts.

The remaining results, in Columns 3-6, show that the effects that I estimate are not being driven by any of the main shipbuilding regions. Column 3 drops the area around New York City (NY, NJ and CT). Column 4 drops the shipbuilding area around Philadelphia and Wilmington (PA and DE). Column 5 drops the traditional wood shipbuilding states of Maine and Massachusetts. Column 6 drops Virginia, which was home to the relatively new Newport News Shipyard.

Table 22 presents additional Navy shipyard results in levels rather than in logs. Focusing on levels allows me to conduct the analysis across all locations available in the data, rather than those that were active only in the 1901-10 period. This is done in Columns 1-3. Columns 4-6 present results using only locations active in 1901-10, the sample that is comparable to the set used in the regressions in the main text. In both cases, being near to a Navy shipyard substantially increases output of metal ships but not wood ships. This effect occurs only within 50km and does not appear from 50-100km.

Table 21: Navy shipyard robustness results

	DV: Log tons produced in a sector-location					
	Locations active in wood ships in 1870	Control for Navy contracts	Drop NY, NJ and CT	Drop PA and DE	Drop Mass. and Maine	Drop VA
	(1)	(2)	(3)	(4)	(5)	(6)
Navy yard within 50km x Metal	2.129*	1.583*	3.582**	2.181*	2.805**	2.603**
	(1.211)	(0.845)	(1.343)	(1.249)	(1.124)	(1.111)
	[1.232]	[0.875]	[0.802]	[0.932]	[1.079]	[1.156]
Navy yard within 50km	-0.791	-1.518***	-0.946	-1.209**	-0.944*	-1.193**
	(0.530)	(0.454)	(0.637)	(0.534)	(0.504)	(0.488)
	[0.559]	[0.509]	[0.518]	[0.552]	[0.301]	[0.507]
Navy contracts x Metal		1.785*				
		(1.011)				
		[0.821]				
Navy contracts		1.693***				
		(0.624)				
		[0.378]				
Observations	64	89	59	79	61	85
R-squared	0.240	0.445	0.287	0.202	0.392	0.246

*** p<0.01, ** p<0.05, * p<0.1 based on SEs clustered by location, shown in parentheses. Standard errors in brackets are clustered on shipbuilding area. Regressions are run on data from U.S. Atlantic Coast locations only. All regressions include controls for whether the sector was metal.

Table 22: Navy shipyard results in levels

	DV: Tonnage produced in a sector-location					
	All locations			Locations active in 1901-10		
	(1)	(2)	(3)	(4)	(5)	(6)
Navy 50km	14,276**	14,191***	14,191***	78,963***	84,068***	84,767***
x Metal	(5,727)	(5,459)	(5,470)	(29,092)	(24,574)	(24,956)
	[8,231]	[6,444]	[6,456]	[26,233]	[25,806]	[24,106]
Navy within 50km	-638.9	-2,374**	-1,823	-7,286*	-5,440	-1,637
	(676.5)	(1,077)	(1,644)	(4,356)	(3,520)	(7,726)
	[646.5]	[903.])	[1,307]	[3,355]	[2,512]	[4,346]
Navy within 100km		-624.6	-624.8		-18,284	-18,792
x Metal		(868.3)	(869.9)		(20,341)	(20,048)
		[799.0]	[801.1]		[14,505]	[15,013]
Navy within 100km		-218.6	-368.9		-4,118	-6,222
		(558.5)	(645.3)		(3,432)	(5,773)
		[528.1]	[453.3]		[3,166]	[4,161]
Metal ind.	Yes	Yes	Yes	Yes	Yes	Yes
Controls for active in 1870s		Yes	Yes		Yes	Yes
County controls			Yes			Yes
Observations	800	800	800	89	89	89
R-squared	0.051	0.279	0.282	0.393	0.534	0.543

*** p<0.01, ** p<0.05, * p<0.1 based on SEs clustered by location, shown in parentheses. Standard errors in brackets are clustered on shipbuilding area. Regressions are run on data from U.S. Atlantic Coast locations only. All regressions include controls for whether the sector was metal. The regressions in Columns 2-3 and 5-6 also include controls for whether a location was active in 1871-1880, whether it was active in the same sector in 1871-1880, total tonnage produced in the location in 1871-1880, and tonnage produced in the same location and sector in 1871-1880. Regressions in Columns 3 and 6 include county-level controls for log population, metalworking employment share and lumber milling employment share.

Table 23 presents results from ML regressions looking at the impact of the Navy shipyards on survival in nearby private yards. As in the main ML results, these regressions are run on yards active at any time during the 1850-1910 period, though the sample includes on those on the Atlantic Coast of the U.S. These results suggest that private yards near Navy shipyards were more likely to be active in both wood and metal shipbuilding (or both together) in 1901-1910, even controlling for previous production patterns. As in the tonnage regressions, all effects disappear when looking outside of 50km. There is some evidence that this effect may have been larger for metal, but this effect is not statistically significant. Overall, these results tell us that proximity to Navy shipyards did not appear to have a strong differential influence on whether a yard remained active in a particular type of shipbuilding. Thus, the clearest effect of Navy shipyards on nearby private yards appears to have been on the intensive margin.

Table 23: Multinomial logit regression looking at Navy Yard effects

	(1)	(2)	(3)	(4)
A=1: Location active in wood shipbuilding only in 1901-1910				
Navy yard within 50km	0.860*	0.797*	1.059*	1.003*
	(0.352)	(0.383)	(0.445)	(0.478)
	[0.384]	[0.479]	[0.477]	[0.581]
Navy yard within 50-100km				-0.148
				(0.466)
				[0.377]
A=2: Location active in metal shipbuilding only in 1901-1910				
Navy yard within 50km	1.884*	2.021	2.489*	2.289
	(0.833)	(1.104)	(1.215)	(1.220)
	[0.690]	[0.589]	[0.802]	[0.818]
Navy yard within 50-100km				-14.127
				(1887.338)
				[0.906]
A=3: Location active in both wood and metal shipbuilding in 1901-1910				
Navy yard within 50km	1.751**	1.450	1.495	1.568
	(0.543)	(0.816)	(1.041)	(1.167)
	[0.425]	[0.608]	[0.830]	[0.873]
Navy yard within 50-100km				0.173
				(1.343)
				[1.297]
Observations	400	400	400	400

*** $p<0.01$, ** $p<0.05$, * $p<0.1$ based on robust SEs, shown in parentheses. Standard errors in brackets are clustered on shipbuilding area. The analysis covers all locations active in shipbuilding from 1850-1910 on the Atlantic Coast of the U.S. Column 2 includes controls for whether a location is active in metal or wood shipbuilding in 1870, separate variables for tonnage produced in metal or wood in 1870, as well as controls for metal or wood shipbuilding at other locations within 100km. Columns 3-4 add in controls for county log population, the county employment share in metalworking industries, and the employment share in lumber.