Reaffirming the Importance of Transport Costs: Evidence from the Trans-Atlantic Iron Trade, 1870-1913[†]

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Abstract

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We use newly compiled evidence on effective transport costs from the trans-Atlantic iron trade to investigate the relationship between trade costs and trade volumes. Like other empirical work on British trade during the late nineteenth and early twentieth centuries, we find a surprisingly weak correlation between ocean freight rates and export quantities. Despite sharply falling trans-Atlantic shipping costs, export volumes stagnated and Britain's role in North America's iron markets declined. However, when we carefully control for endogenous shipping costs, tariffs and prices, and account for the full range of transport costs that affect trade, including overland transport costs, insurance, wharfage and brokerage fees for both final goods and raw material inputs, the importance of transportation reasserts itself. We find that effective transport costs had a strong and underappreciated impact on the total tonnage shipped.

1. Introduction

Despite the complex nature of the relationship linking transport costs and trade volumes, it is widely accepted that falling ocean freight rates have contributed to the expansion of international trade.[1] Focusing on the growth in trade volumes that occurred during the late nineteenth and early twentieth centuries, O'Rourke and Williamson (1999: 35) argue that, "...the decline in transport costs after mid-[nineteenth] century was enormous, and it ushered in a new era [of globalization]." Echoing this conclusion, Estevadeordal, Frantz and Taylor (2003: 362) report that, "[t]ransport costs on maritime routes played a big role in both [trade] boom and bust: they fell dramatically before 1914...[and] rose steeply up to 1939." Based on estimates of falling distance effects, Jacks (2009: 232) provides statistical support for the standard view, concluding that, "...[after 1870]...the spread of communication [and] transport networks lowered trade costs, and thus, stimulated trade flows."

Empirical confirmation of the impact of transport costs on trade has suffered from a scarcity of direct evidence on route and product-specific freight rates, overland transport costs, and the myriad of other charges and fees associated with the movement of goods across borders. In part as a result of this evidentiary hole, the notion that trans-oceanic shipping costs have been an important determinant of international trade flows, particularly during the 1870-1913 period, has recently become the subject of some skeptical investigative scrutiny.[2] Jacks and Pendakar (2010) study the relationship linking British trade flows to partner-specific freight rates. After instrumenting to control for endogeneity, they find (2010: 745), “...little systematic evidence suggesting that the maritime transport revolution was a primary driver of the late-nineteenth century global trade boom." They suggest (2010: 753) a number of possible explanations for the absence of a freight rate-trade link in their study, including their inability to fully control for all determinants of transport and trade costs. Other charges, including wharfage,

[1] On the organizational and technological improvements in late nineteenth century ocean shipping see North (1968), Harley (1988), Lew and Cater (2006), or Mohammed and Williamson (2004).

[2] There is an ongoing debate in the contemporary empirical trade literature about the importance of ocean shipping which focuses on changes in the size and significance of the distance variable in gravity model specifications. For example see Bernanke (2006) and Levinson (2006) who see shipping charges as important, or Disdier and Head (2008) and Hummels (2001) who down-play the importance of freight rates.

brokerage fees, insurance, overland freight rates, tariffs, and exchange rate effects, could potentially offset any impact freight rates might have on trade volumes.

The difficulties associated with the measurement of all trade cost determinants is not the only empirical hurdle researchers face. Further uneasiness about the freight rate-trade relationship may arise from a recognition that the falling transport costs documented by Jacks and Pendakar affect *all* traded goods, including raw materials and intermediate inputs. It is not gross transport costs, but effective (or net) costs that influence the incentive to engage in international trade. If it becomes cheaper to assemble raw materials in an import competing nation, then trade may be suppressed. In light of these empirical challenges, an assessment of the strength of the relationship linking ocean freight rates and effective transport costs to trade volumes seems to call for a finely detailed route and product-specific case study. In this paper we undertake this assessment for one of the more important, and widely studied, trade relationships of the 1870-1913 period: the trans-Atlantic iron trade.

Using newly compiled annual information on west-bound trans-Atlantic ocean freight rates for pig iron, with estimates of British and North American overland rail charges, wharfage, brokerage fees and insurance, we calculate gross transport costs for the shipment of iron from Britain to both Pittsburgh PA (through New York City) and Hamilton ON (through Montreal) for the years 1870-1913. We derive effective transport cost figures by netting out the cost to move iron ore from Michigan and coke from Pennsylvania to the blast furnaces in Pittsburgh and Hamilton. Effective tariff protection is calculated using nation-specific pig iron duties less iron ore and coke duties, all measured per net ton of pig iron. We also consider exchange rate volatility and adherence to the gold standard as potential trade cost determinants.

We use these trade cost variables in import demand functions, which include additional controls for technological discontinuities, domestic demand, foreign and domestic output prices, GDP similarities among trade partners, and lagged trade volumes. An instrumental variables (IV) approach is adopted to control for the endogenous nature of the relationship between transport costs, tariff rates and domestic output prices, on one hand, and trade volumes, on the other.

We find that after controlling for other influences on import demand, falling trans-Atlantic freight rates were associated with rising British pig iron exports into the US and Canada, but the elasticity implied by this relationship is small and (at best) marginally statistically distinguishable from zero. When we broaden our assessment of transport and trade costs to include overland rail charges, wharfage, brokerage fees, insurance, and tariffs, the elasticity of British exports with respect to transport costs becomes larger and statistical significance is strengthened. However, it is only after we consider effective trade costs, by netting out transport costs associated with the intra-continental movement of iron ore and coke, and control for the endogenous nature of the transport-trade relationship, that we can identify a considerably more elastic and statistically robust link to trans-Atlantic trade volumes. It appears, therefore, that trade flows were sensitive to effective transport costs between 1870-1913, but as just a single determinant of total tonnage shipped, identifying the impact of falling trans-Atlantic freight rates is complicated by the presence of coincident changes in other transport costs, tariffs, relative prices and North American demand conditions.

The elasticities derived from our import demand functions can be used to reveal the extent to which transportation has been underappreciated in the research effort that has sought to explain the collapse in Britain's iron trade after 1870.[3] We use a series of counterfactual simulation exercises to assess the impact of falling relative output prices, changing tariff policies, and changing transport costs on Britain's trans-Atlantic pig iron exports. The results from these exercises reveal that changes in effective transport costs were very nearly as important as falling relative prices in the determination of the quantity of British exports into North American iron markets between 1870-1913.

2. Producing and Trading Pig Iron

A nation's ability to produce iron and its products at competitive prices has often been taken as an indicator of an advanced stage of industrial development. Pig iron is an intermediate input produced by smelting iron ore with high carbon content fuels such as

[3] Among the key contributors to the debate about the causes of British export failure in pig iron, neither Temin (1966), McCloskey (1973), nor Allen (1979) even mention trans-Atlantic freight rates. Irwin (2000) and Davis and Irwin's (2008) more recent work on the US pig iron industry emphasizes the role played by tariffs, again ignoring transport costs.

charcoal or coke. The molten metal that results from this process can be poured into moulds to form bars or slabs, which can then be further refined to oxidize a range of impurities, forming either wrought iron or steel. The production of pig iron relies on techniques that make intensive use of both human and physical capital. To be efficient, blast furnaces, foundries and rolling mills must be technologically advanced, organizationally complex and capable of exploiting scale economies inherent in their production processes.[4]

In Canada during our period of study there were three very distinct phases in the development of the domestic iron industry.[5] Until the last years of the 1870s production was dominated by five small, charcoal fuelled blast furnaces in the province of Quebec. Although the Londonderry Company had been in production in Nova Scotia since 1853, it was not until coke was introduced as a primary fuel source during the late 1870s and early 1880s that investment and production began to expand rapidly outside of Quebec. By the turn of the twentieth century Quebec's furnaces were producing less than 5% of Canada's domestic pig iron, and large scale, coke burning integrated iron and steel works were in operation in Hamilton ON, Sault St. Marie ON, and Sydney NS. In 1913 Stelco (in Hamilton), Algoma (in Sault St. Marie), and Dominion Steel and Coal (in Sydney) produced more than 657,000 net tons of pig iron, 79% of all pig iron produced in Canada and almost 50% of all pig iron consumed in Canada.[6] The move from small scale charcoal burning furnaces to larger coke burning furnaces at the end of the 1870s marks the first technological transition in the Canadian industry, and the construction of large, complex, technologically advanced steel works through the mid-1890s marks a second transition.

These technological transitions arrived earlier in the US and they were considerably less abrupt, but they are still identifiable in the evidence on American mills'

[4] For more on British and North American technological characteristics and their economic implications see Allen (1977) or Inwood (1986).

[5] Although Canada produced far less pig iron than both the US and Britain, the Canadian market was important to British blast furnaces, the Canadian and US markets appear to have been viewed as close substitutes by British exporters, and Canadian transport costs and tariffs did not mirror US costs and tariffs. A comprehensive investigation of the trans-Atlantic trade in pig iron, therefore, benefits from the inclusion of both North American markets.

[6] All quantities used in this paper have been converted to 2,000 lbs net tons.

fuel use and steel production.[7] In aggregate, the US pig iron industry, centred in Pittsburgh PA, dwarfed the Canadian industry. By the early 1890s US production matched British levels at approximately 9 million net tons, and by 1913 the US produced more pig iron than any other nation, smelting just over 30 million net tons during that year. In every year covered by our study the US industry used proportionately more coke and produced proportionately more steel than the Canadian industry.

Insert Figure 1a and 1b

In Figure 1a we depict the total quantity of pig iron produced by US, Canadian and British blast furnaces in each year between 1870-1913. The relatively slow growth of the British industry that has motivated much of the British failure literature, and the small size of Canadian industry are both clearly evident.[8] Of course, large and rapidly growing US output levels do not necessarily imply that Canadian production (and the Canadian market) was inconsequential in the trans-Atlantic iron trade. In Figure 1b we provide another perspective on the relative size of these industries, illustrating per capita pig iron output. In 1913 Canadian blast furnaces produced 293 lbs of pig iron for every Canadian citizen - an increase of nearly 290 lbs per person since 1870. In contrast, US pig iron production increased from 76 lbs per person in 1870 to 567 lbs in 1913, and the British industry produced 561 lbs per person in 1913, an increase of just 31 lbs since 1870. A macroeconomic perspective provides yet another illustration of the size and rate of growth of the Canadian industry in a comparative context that is not dominated by scale differences. From very low initial levels, Canadian pig iron production was growing nearly 12% faster than domestic real GDP between 1870-1913, while US production was growing just 7% faster than real GDP, and British production was actually shrinking by 0.5% relative to real GDP.

The late nineteenth and early twentieth century trans-Atlantic iron trade is a particularly good case study for our purposes because of the important role played by transportation costs in US and Canadian markets. Ocean freight rates consistently

[7] See *US Historical Statistics Millennial Edition*, Series Dd399, Davis and Irwin (2008: Table 2), or Allen (1977: Footnote 23).

[8] The large literature on the relative decline of the British industry during the late nineteenth century emphasizes the effects of technological choice and input market conditions on relative output prices. For a concise review see Broadberry (1997, Chapter 10). We do not seek to provide internal explanations for British stagnation, but our results are conditional on the inclusion of appropriate controls for British, American and Canadian output price differences.

accounted for a substantial proportion of the North American price of imported British pig iron. In 1870 the cost to transport pig iron across the Atlantic accounted for 16% of the price for a net ton of iron in Philadelphia and 18% of the Montreal price. At the time, a net ton of pig iron cost $25.78 (CAD/net ton) in Philadelphia and $24.33 in Montreal. In 1913 the cost to move a net ton of pig iron from British ports to New York City had fallen to just $0.83 (5.5% of the Philadelphia price), while it still cost just over $3.00 to ship iron into Montreal (13% of the local price).

Of course, the decline in ocean freight rates for the trans-Atlantic iron trade did not occur in a vacuum. The years between 1870-1913 also saw a dramatic increase in North American demand for the products that used pig iron as a primary intermediate input. Real GDP per capita grew at an average annual rate of 2.1% between 1871-1911 in Canada (1.8% in the US), the urban share of total population grew by 2.1% per year in the US (4.2% in Canada), railway mileage increased at an average rate of 5.6% in Canada (3.7% in the US), and real gross fixed capital investment increased by 4.9% per year in the US (5.6% in Canada).

Insert Figure 2a and 2b

Figure 2a depicts the total quantity of British pig iron shipped into the United States and Canada in each year between 1870-1913, while Figure 2b depicts the share of North American pig iron consumption supplied by these imports. In light of the falling freight rates and expanding North American demand, plausible import demand elasticity estimates would lead us to expect a substantial increase in trans-Atlantic pig iron trade volumes over the 1870-1913 period.[9] In general, these macroeconomic conditions were coincident with trade expansion. In aggregate, British real domestic exports very nearly doubled between 1870 and 1913 (Mitchell and Deane, 1963, Table 11.3). However, as we can see from Figures 2a and 2b, British pig iron exports into Canada increased only slightly over this period, tonnage shipped into the US dropped, and Britain's share of the Canadian and American iron markets fell sharply. In 1913 Britain shipped just 118,700 tons of pig iron to the United States (a 16,000 ton decrease from the total tonnage shipped in 1870), which accounted for less than one half of one percent of US consumption. In

[9] For example, based on the US market for pig iron from 1867-1889, Irwin (2000, Table 1) reports import price demand elasticities that range from -2.1 to -2.6.

Canada in 1913 nearly 79,000 tons of British pig iron entered the market, but this represented only slightly more than 5% of domestic consumption, down from 30% in 1870. Why did the trans-Atlantic trade in pig iron collapse just as ocean freight rates were falling sharply? It is this dramatic illustration of the apparent insensitivity of trade volumes to movements in freight rates that motivates our investigation in this paper.

3. Trade Determinants

Trade costs drive a wedge between the prices received by producers and the prices paid by consumers who transact on geographically distant markets. The larger this wedge, the less incentive there is to ship products to more dispersed markets, and therefore, the less integrated international goods markets will be. Pig iron is dirty, heavy, awkward to handle, and cheap to produce. This implies that trade costs for pig iron are likely to be substantial, and the size of the trade cost wedge should have a particularly important impact on its movement between distant markets, such as Britain and New York City (2978 nautical miles), or Britain and Montreal (2812 nautical miles).

Insert Figure 3a

Trade costs can originate from many sources. We group these sources into three broad categories: transport costs, tariffs, and exchange rate effects. In Figure 3a we illustrate the cost to ship a net ton of pig iron from ports on Britain's north-east coast to New York City and Montreal in each year between 1870-1913. These freight rates are specific to the westbound shipment of pig iron, and they have been collected from a wide range of sources, including Angier's (1920) *Fifty Years of Freights*, the periodical *Iron Age*, British Board of Trade reports, and the 1914 British Dominions Royal Commission.[10] Although there is considerable volatility from year-to-year, in general trans-Atlantic pig iron freight rates were trending sharply downwards after 1870.

At the start of our period of study it cost $4.40 (CAD) to transport a net ton of pig iron from Britain to Montreal. This product and route-specific rate peaked in 1880 at $4.53, fell as low as $1.81, and ended our period of study at $3.02 in 1913 - a 33% decline since 1870. Britain to New York City freight rates were lower than the UK-

[10] A complete Data Appendix with information on sources, composition and construction for all series used in this paper can be accessed at: http://www.econ.queensu.ca/files/other/irondataapp.pdf

Montreal rates in every year but one (1891), they fell from $4.13 (CAD) per net ton in 1870 to a minimum of $0.37, and they ended our period of study at $0.83 - an 80% decline since 1870. To provide some comparative context we can consider reductions in other widely cited British freight rate indexes over the same 1870-1913 period, including a 34% decline in Isserlis (1939) average British shipping cost index, an 84% drop in North's (1958) American export freight rates (1870-1910), and a 54% drop in Harley's (1989) westbound trans-Atlantic shipping costs for coal, from $4.26 CAD per net ton in 1870 to $2.13 in 1913. Mohammed and Williamson's (2004) global freight rate index falls by 69% between 1870-1913, their eastbound trans-Atlantic grain index falls by 71%, and Jacks and Pendakar's (2010) non-parametric, partner-specific British shipping cost index falls by 45%.

The total cost to ship pig iron from British blast furnaces to North American foundries and steel mills is not fully captured by trans-Atlantic freight rates. A full accounting of pig iron's transport costs must include the cost to move the iron to and from port facilities, wharfage charges, brokerage fees, and insurance.[11] For each year between 1870-1913 we include the cost to load and move pig iron by rail from British blast furnaces to British port facilities, and from New York and Montreal port facilities to the primary North American consumption points in Pittsburgh and Hamilton. Rail charges specific to pig iron are derived from the periodical *Iron Age*, with interpolation across missing years based on freight revenue per ton-mile for British, American and Canadian rail systems. Brokerage fees and insurance rates for pig iron are again taken from *Iron Age*, with exponential decay assumed for insurance rates and a fixed percentage of unit value assumed for brokerage. Wharfage for the Montreal docks is taken from reports in the *Montreal Times*, while New York wharfage is determined on the basis of average registered tonnage (as reported in various newspaper reports on vessels involved in the pig iron trade) and the official per ton rates legislated by New York State.

Insert Figure 3b

A comparison of the freight rate series depicted in Figure 3a and the full transport cost series depicted in Figure 3b illustrates the importance of overland and supplementary

[11] Persson (2004, Pg. 137-139) discusses the challenges involved in the derivation of port charges and insurance rates for the nineteenth century trans-Atlantic grain trade. His estimate of the size of these charges relative to port-to-port freight rates is similar to our findings for the iron trade.

charges in the total cost to move pig iron. On average between 1870-1913 rail, wharfage, brokerage and insurance costs exceeded the cost to ship pig iron from port-to-port across the Atlantic by more than 27% on the UK-Montreal route and by nearly 80% on the UK-New York route. In 1890, for example, it cost $4.55 CAD per net ton to ship pig iron from British blast furnaces to Pittsburgh steel mills, of which the ocean freight rate accounts for only $2.08. In the same year it cost $6.39 CAD per net ton to ship to Hamilton's steel mills, but the trans-Atlantic part of the trip only cost $3.02. Gross transport costs fell by 47% between 1870-1913 on the Canadian route (slightly faster than the drop in the UK-Montreal freight rate alone), and 65% on the US route (slightly slower than the UK-New York City freight rate alone).

Transport costs affect trade not only because they affect the cost of British imports, but also because they affect raw material prices, and hence the cost to produce domestically. It is the net, or effective cost of transportation faced by North American blast furnaces that determined their ability to compete with British imports. The broad shipping cost indexes from our period of study indicate that the reductions in transport costs we document for pig iron were not product or route specific. Falling transport costs also affected the cost to assemble raw materials for the production of pig iron. With few exceptions, Canadian and US blast furnaces acquired their raw materials from geographically proximate sources - iron ore from the upper Great Lakes, including Marquette Michigan, and coke from Connellsville Pennsylvania.[12]

We estimate effective transport costs by subtracting the cost to ship iron ore from Marquette and coke from Connellsville to the blast furnaces in Pittsburgh and Hamilton, from the gross trans-Atlantic transport costs depicted in Figure 3b. Iron ore transport costs include a fresh-water freight rate from ports in the upper Great Lakes to ports in the lower Great Lakes, insurance, brokerage fees, and rail charges for the shipment of ore from the mine head to the upper lake ports and from the lower lake ports to Hamilton and Pittsburgh. Coke transport costs include rail charges from the Connellsville kilns to Pittsburgh and, through Buffalo NY, to Hamilton. In addition to the sources already

[12] Not all iron ore used in all North American blast furnaces came from Marquette, and not all fuel came from Connellsville, but a substantial and increasing proportion did come from these sources, or very near to them. For more detail on input sources see Inwood (1983) for Canada and Allen (1977: Notes to Appendix Table 1 and 2) for the US.

mentioned, raw material transport cost information has been taken from the Lake Carriers' Association publication, *The Iron Ores of Lake Superior*.

Insert Figure 3c

From Figure 3c we can see that per net ton of pig iron, raw material transport costs consistently exceeded trans-Atlantic transport costs (*Effective Transport Costs* are negative), and intra-continental shipping costs were falling even faster than inter-continental shipping costs (*Effective Transport Costs* were rising over time).[13] In 1870 the cost to move enough iron ore and coke to produce a net ton of pig iron from their US extraction points to Hamilton, exceeded the cost to move a net ton of pig iron from Britain to Hamilton by $6.55 CAD. This differential shrank over the next forty-four years to such an extent that by 1913 the trans-Atlantic shipping costs were actually $0.16 higher than the intra-continental shipping costs faced by Canadian blast furnaces - an average annual rate of change in effective transport costs of more than +1.6%. For the US producers intra-continental raw material shipping costs per net ton of pig iron were $4.16 CAD higher than the inter-continental shipping costs in 1870, and this differential fell by 1.4% per year, to just $0.89 in 1913. It is also interesting to note that the difference between Canadian and US effective transport costs were much smaller than the gross transport cost difference, indicating the relatively favourable geographic location of US steel production, with Pittsburgh located less than 50 miles from Connellsville.

Effective transport costs are just one source of trade costs, which may be offset or augmented by other sources. It is not unusual, for example, for interested parties to petition governments for changes in tariff protection in response to perceived changes in effective transport costs.[14] Governments may impose tariffs on output products and/or raw material inputs in an effort to alter aggregate trade costs in a politically or economically advantageous manner. In the United States the imposition of pig iron tariffs motivated a long and heated political battle during the years following the conclusion of the Civil War.[15] This battle culminated in substantial reductions in the

[13] This finding is consistent with the relative rates of change in over-land versus over-water shipment costs anticipated by O'Rourke and Williamson (1999, Pg. 41).
[14] For discussion of the late nineteenth century transport-tariff trade-off see Williamson (2003, Pg. 27) or Fremdling (2005, Pg. 92).
[15] Irwin (2000, Pg. 280-83) describes the US Government's slow move towards free trade in pig iron during this period.

gross pig iron tariff in 1883, 1894 and 1912. Between 1879-1882 the US pig iron tariff was at its maximum for our period of study: \$6.25 CAD per net ton.[16] Between 1893 and 1894 the pig iron tariff dropped from \$6.00 per net ton to \$3.57, and by 1913 the US was admitting pig iron imports free of duty. We calculate effective tariff protection by subtracting iron ore and coal tariffs from the gross pig iron tariff. Raw material duties were low throughout our period of study, with US iron ore tariffs reaching a maximum of \$1.17 CAD per net ton of pig iron between 1883-1893 and US coal tariffs reaching a maximum of \$1.40 in 1870 and 1871.[17] By 1913 iron ore was entering the US at a rate of just \$0.23 per net ton of pig iron, and coal was entering at just \$0.50 per net ton.

Insert Figure 4

From Figure 4 we can see that the effective tariff protection afforded pig iron followed a very different trajectory over the 1870-1913 period in Canada relative to the US. While American tariffs on pig iron moved steadily towards free trade from initially high levels, there were no Canadian tariffs on pig iron (or the raw materials used in its production) until the imposition of a \$2.00 per net ton duty as part of the National Policy tariffs in 1879. An additional \$0.50 increase in 1884 was followed quickly by a doubling of the gross pig iron tariff rate to \$5.00 under the Tupper tariffs in 1888, with a final increase to \$6.00 in 1893-1895. By 1913 pig iron entering Canada faced a tariff rate that averaged \$2.13, with a slight preference afforded British imports. Throughout the 1870-1913 period coal entered Canada duty free, and iron ore faced only a small \$0.63 per net ton of pig iron tariff between 1879-1893.

Insert Figure 5

Figure 5 illustrates the combination of effective transport protection per net ton of pig iron (as depicted in Figure 3c) and effective tariff protection per net ton of pig iron (as depicted in Figure 4), divided by North American pig iron prices. We can see that *ad valorem* effective protection for Canadian pig iron producers was negative from 1870 until 1884, but it rose from a minimum of -26.1% in 1876 to a maximum of +24.6% in

[16] US pig iron and coal tariffs were quoted at specific rates per ton between 1870-1913. US iron ore tariffs were quoted at specific rates from 1883-1913. *Ad valorem* tariff rates on iron ore have been converted to \$/ton using UK iron ore export prices. US tariff rates from Taussig (1931).

[17] US blast furnaces relied heavily on domestic raw material supplies. In aggregate, coal and iron ore imports were small compared to domestic consumption, and according to Taussig (1931, Pg. 231-232) ore tariffs in particular were paid by only a few firms located close to the Atlantic coast. Sensitivity tests have been performed using only gross US pig iron tariffs (see Table 4: *Test 1*).

1898, settling in 1913 at just slightly under +10%. US *ad valorem* effective protection was consistently higher than Canadian protection up to 1893, after which it was consistently lower, ending the period at -10.7%, 33.4 percentage points lower than its 1893 peak. Blast furnaces in both nations enjoyed sharply rising effective protection over the first twenty-five years of our period of study, coincident with raw material transport costs that were falling considerably faster than trans-Atlantic freight rates, and in Canada at least, rising tariffs. Over the final twenty years of our period of study effective protection for Canadian and US pig iron producers fell as the rate of decline of inter and intra-continental transport costs stagnated and effective tariff protection was reduced.

Others have eloquently argued that as a result of their connection to risk and transactions costs, fluctuations in foreign exchange rates also have an impact on international trade costs.[18] For the trans-Atlantic iron trade the impact of exchange rate volatility and adherence to the gold standard is likely to have been small, at least relative to transport and tariff effects, because all three trade partners were strong proponents of the late nineteenth century fixed exchange rate regime. Canada and Britain maintained bilateral fixed exchange rates, tied to gold, throughout the 1870-1913 period. The result is very low exchange rate volatility between Canada and Britain, with an average five year centred standard deviation of just 0.003. The United States and Britain also maintained bilateral fixed change rates for most of our period of study, but on average between 1870-1913 the five year centred standard deviation of US and British exchange rates is 0.012 - almost four times more volatile than the Canada-UK exchange rate. Virtually all of this additional volatility manifested itself during the immediate post-Civil War period. Between 1870-1878 US exchange rate volatility was considerable as the US government struggled to depreciate the US Greenback and return to the gold standard at the pre-Civil War rate of exchange.

Of course, trade costs are not the only determinant of trade volumes. Imported pig iron may be viewed as an imperfect substitute for domestically produced pig iron.[19] As such, we might reasonably expect North American and British pig iron prices to affect

[18] Lopez-Cordova and Meissner (2003) identify a connection between adherence to the gold standard and trade flows during our period of study, while Jacks, Novy and Meissner (2011) discuss the relationship between the gold standard, exchange rate volatility and trade costs.

[19] For detailed discussion of nineteenth century elasticity of substitution between domestic and foreign pig iron see Davis and Irwin (2008, Pg. 265).

trade volumes, with rising domestic prices providing an incentive to trade and rising British prices suppressing trade. It is not only prices in the destination country that can affect the quantity of pig iron shipped, but price movements in the neighbouring North American market may also divert trade. From Table 1 we can see that on average Summerlee No. 2 pig iron prices in Montreal were higher than No. 1 foundry pig iron prices in Philadelphia, which were considerably higher than Cleveland No. 3 pig iron prices in Britain. However, as the British failure literature has described in great detail, British domestic prices were rising gradually over our period of study, while prices in Canada were gradually falling and US prices were dropping sharply, particularly during the 1870s. The price of a net ton of pig iron in Philadelphia relative to Britain fell from 2.5 in 1870 to just 1.2 in 1913, while the Montreal / UK price differential fell from 2.1 to 1.6.

Insert Table 1

Pig iron is an intermediate good used in the production of a wide range of iron and steel products. In the late nineteenth and early twentieth centuries most iron and steel products were not purchased by individuals as consumption goods, but rather by firms and governments as investment and infrastructure goods. Domestic demand for pig iron, therefore, is not well represented by more typical demand determinants, such as GDP per capita or real wages. Real gross fixed capital investment seems like a better measure of domestic demand for the machinery, equipment and construction materials produced with pig iron. US gross fixed capital accumulated steadily through our period of study, increasing at an average annual rate of nearly 5%. In contrast, Canadian investment was discontinuous, growing by only 1.6% per year over the 1870-1895 period, before expanding in dramatic fashion (by more than 11% per year) during the "wheat boom" era.

Because the products produced with pig iron during the late nineteenth and early twentieth centuries were technologically advanced, and they were used in the production of infrastructure that was being built to accommodate rapid urban and industrial development, we expect nations with similar levels of economic development to be more inclined to participate in the international iron trade. Most standard gravity model specifications assess the extent to which trade partners have similar levels of development with a simple measure of the "proximity" of trade partners' GDP levels. In

Table 1 we can see that although Canadian and British GDP levels differed by more than US and British GDP levels, the Canadian difference was shrinking over our period of study while the US difference was growing. Although it cannot be seen from the summary statistics in Table 1, the annual data reveals that after two and a half decades of little movement, Canadian and British GDP levels were becoming rapidly more similar after 1896.

The production of pig iron during our period of study has been the subject of much scholarly interest not only due to its importance in the process of industrial development, but also because of the discontinuous nature of the technological changes that transformed iron and steel industries.[20] The move away from charcoal and the adoption of coke as a primary fuel source dramatically altered the cost structure of North American blast furnaces and it significantly affected the geographic range of economically feasible production locations, which in turn affected the incentive to trade iron across international borders. The proportion of coke burning furnaces in the United States began to grow well before 1870 and the transition was relatively smooth as obsolete furnaces were taken out of commission and replaced with larger facilities that were not as closely tied to a local resource stock capable of supporting charcoal production. In contrast, the adoption of coke as a primary fuel source in Canada was very abrupt. With only one exception (Londonderry NS) by 1870 Canadian charcoal burning furnaces were located exclusively in south-western Quebec, but in a very few years at the end of the 1870s these furnaces saw their share of domestic pig iron production drop from almost 100% to near zero. The new firms that opened in Nova Scotia and Ontario relied overwhelmingly on coke to fuel their furnaces.

The technological transformation associated with the move towards integrated steel mills in both Canada and the US was also abrupt. The adoption of the Bessemer process promoted the use of molten pig iron in the production of steel. As this implies, this process affected trade incentives because it introduced a cost advantage associated with the integration of pig iron production, steel production and rolling mills into large, complex, coordinated mills. The cold-metal to hot-metal technological transformation in

[20] The economic consequences of these transformations is discussed in detail in Allen (1979). For more descriptive detail on the Canadian experience see Donald (1915) or Inwood (1986).

Canada was embodied in the nearly coincident construction of integrated steel mills in Hamilton (1896), Sydney (1901) and Sault St. Marie (1904). In the US this technological transformation coincided with an increase in industrial concentration following the formation of Carnegie Steel (1892) and US Steel (1902) in Pittsburgh.

4. Import Demand Functions

International trade theory tells us that the quantity of pig iron shipped across the Atlantic from Britain to North America between 1870-1913 should be related to trade costs that result from effective transport protection, effective tariff protection and exchange rate effects, as well as output prices in the destination markets, the price of foreign substitutes, domestic demand for products made from pig iron, an indicator of economic development similarities among trade partners, and technological discontinuities in the production of iron and steel. With access to a broad panel of countries we could assess the relative strength of these potential trade determinants using a gravity model framework, including distance, GDP and lagged trade volumes (to allow for the possibility that export responses may not be exhausted within each year) as additional explanatory variables. However, because we are interested in the exchange of a single product along just two trans-Atlantic trade routes, a typical gravity model approach is inappropriate. The uni-directional trade of a specific product between two partners can be more appropriately modeled using import demand functions.[21]

We have borrowed heavily from both import demand and gravity model methodologies in the specification of our empirical approach. Our objective in adopting this approach is to narrowly focus on the relationship between British trans-Atlantic pig iron exports and transport costs, controlling for other trade costs, import demand determinants, and technological discontinuities. In general, the functions we estimate take the form:

$$\textit{British Exports}_{it} = f\,[\textit{Trade Costs}_{it}, \textit{Import Demand Determinants}_{it}, \textit{Technology}_{it}, \textit{Fixed Effects}_{i}]$$

[21] For a review of the extensive literature using import demand functions see Sinha and Sinha (2000). Estimation approaches and endogeneity concerns associated with import demand functions are discussed in Kee, Nicita and Olarreaga (2008).

Where: *British Exports* = net tons of pig iron; *i* = Canada, US; *t* = 1870-1913; *Trade Costs* = exchange rate volatility, gold standard dummy[22], effective tariffs, and effective transport costs; *Import Demand Determinants* = domestic price, British price, other North American price, real gross fixed investment, GDP similarity[23], and lagged British exports; *Technology* = charcoal dummy, and hot-metal dummy[24]; *Fixed Effect* = Canada dummy.

We specify seven models based on this general functional form, each of which represents a discrete increase in our ability to control for different dimensions in the complex transport cost-trade relationship. The first model captures the unconditional correlation between ocean freight rates and trade volumes for the trans-Atlantic iron trade. The second model includes controls for the standard import demand determinants, including those changes in British, American and Canadian pig iron prices that the British failure literature has emphasized as the key triggers for the late nineteenth century collapse of the British iron trade. The third model includes additional controls for exchange rate effects and technological discontinuities. In the fourth model gross tariffs are included, while in the fifth model we subtract duties imposed on iron ore and coal from the gross tariff rates before including effective tariff rates. All other transport charges, including rail costs to and from British and North American port facilities, brokerage fees, wharfage and insurance, are added to freight rates to derive the gross transport costs that are included in the sixth model. And finally, in the seventh model effective transport costs are included, which are calculated by subtracting costs associated with the intra-continental movement of iron ore and coke from their US extraction points to the primary consumption points in Pittsburgh and Hamilton, from gross pig iron transport costs.

[22] Exchange rate volatility is measured as the 5 year centred standard deviation of the official Canada-UK and US-UK exchange rates. The gold standard dummy takes the value 1 during adherence to fixed exchange rates, 0 otherwise: Canada = 1 from 1870-1913; US = 0 from 1870-1878 and 1 from 1879-1913.
[23] Following Jacks and Pendakar (2010: 750) GDP similarity = ln [$(GDP_{UK}/(GDP_{UK}+GDP_i)) \times (GDP_i/(GDP_{UK}+GDP_i))$].
[24] The charcoal dummy takes the value 1 during intensive use of charcoal as a primary fuel input, 0 otherwise: Canada = 1 from 1870-1878 and 0 from 1879-1913; US = 0 from 1870-1913. The hot-metal dummy takes the value 1 when integrated steel mills dominate, 0 otherwise: Canada = 0 from 1870-1895 and 1 from 1896-1913; US = 0 from 1870-1902 and 1 from 1903-1913. Sensitivity tests have been performed using two hot-metal dummies, one for early mills (1892) and one for late mills (1902) (see Table 4: *Test 2*).

Model 1:

$$\text{British Exports}_{it} = \alpha 0 + \beta 1\ \text{Ocean}_{it} + \alpha 1\ \text{Canada}_{i} + \varepsilon_{it}$$

Model 2:

$$\text{British Exports}_{it} = \alpha 0 + \beta 1\ \text{Ocean}_{it} + \gamma 1\ \text{Own Price}_{it} + \gamma 2\ \text{British Price}_{it} + \gamma 3\ \text{Other NA Price}_{it} + \gamma 4\ \text{Gross Investment}_{it} + \gamma 5\ \text{GDP Similarity}_{it} + \gamma 6\ \text{British Exports}_{it-1} + \alpha 1\ \text{Canada}_{i} + \varepsilon_{it}$$

Model 3:

$$\text{British Exports}_{it} = \alpha 0 + \beta 1\ \text{Ocean}_{it} + \beta 3\ \text{XRate Volatility}_{it} + \beta 4\ \text{Gold Standard}_{it} + \gamma 1\ \text{Own Price}_{it} + \gamma 2\ \text{British Price}_{it} + \gamma 3\ \text{Other NA Price}_{it} + \gamma 4\ \text{Gross Investment}_{it} + \gamma 5\ \text{GDP Similarity}_{it} + \gamma 6\ \text{British Exports}_{it-1} + \alpha 1\ \text{Canada}_{i} + \delta 1\ \text{Charcoal}_{it} + \delta 2\ \text{Hot-Metal}_{it} + \varepsilon_{it}$$

Model 4:

$$\text{British Exports}_{it} = \alpha 0 + \beta 1\ \text{Ocean}_{it} + \beta 2\ \text{Gross Tariff}_{it} + \beta 3\ \text{XRate Volatility}_{it} + \beta 4\ \text{Gold Standard}_{it} + \gamma 1\ \text{Own Price}_{it} + \gamma 2\ \text{British Price}_{it} + \gamma 3\ \text{Other NA Price}_{it} + \gamma 4\ \text{Gross Investment}_{it} + \gamma 5\ \text{GDP Similarity}_{it} + \gamma 6\ \text{British Exports}_{it-1} + \alpha 1\ \text{Canada}_{i} + \delta 1\ \text{Charcoal}_{it} + \delta 2\ \text{Hot-Metal}_{it} + \varepsilon_{it}$$

Model 5:

$$\text{British Exports}_{it} = \alpha 0 + \beta 1\ \text{Ocean}_{it} + \beta 2\ \text{Effective Tariff}_{it} + \beta 3\ \text{XRate Volatility}_{it} + \beta 4\ \text{Gold Standard}_{it} + \gamma 1\ \text{Own Price}_{it} + \gamma 2\ \text{British Price}_{it} + \gamma 3\ \text{Other NA Price}_{it} + \gamma 4\ \text{Gross Investment}_{it} + \gamma 5\ \text{GDP Similarity}_{it} + \gamma 6\ \text{British Exports}_{it-1} + \alpha 1\ \text{Canada}_{i} + \delta 1\ \text{Charcoal}_{it} + \delta 2\ \text{Hot-Metal}_{it} + \varepsilon_{it}$$

Model 6:

$$\text{British Exports}_{it} = \alpha 0 + \beta 1\ \text{Gross Transport}_{it} + \beta 2\ \text{Effective Tariff}_{it} + \beta 3\ \text{XRate Volatility}_{it} + \beta 4\ \text{Gold Standard}_{it} + \gamma 1\ \text{Own Price}_{it} + \gamma 2\ \text{British Price}_{it} + \gamma 3\ \text{Other NA Price}_{it} + \gamma 4\ \text{Gross Investment}_{it} + \gamma 5\ \text{GDP Similarity}_{it} + \gamma 6\ \text{British Exports}_{it-1} + \alpha 1\ \text{Canada}_{i} + \delta 1\ \text{Charcoal}_{it} + \delta 2\ \text{Hot-Metal}_{it} + \varepsilon_{it}$$

Model 7:

$$\text{British Exports}_{it} = \alpha 0 + \beta 1\ \text{Effective Transport}_{it} + \beta 2\ \text{Effective Tariff}_{it} + \beta 3\ \text{XRate Volatility}_{it} + \beta 4\ \text{Gold Standard}_{it} + \gamma 1\ \text{Own Price}_{it} + \gamma 2\ \text{British Price}_{it} + \gamma 3\ \text{Other NA Price}_{it} + \gamma 4\ \text{Gross Investment}_{it} + \gamma 5\ \text{GDP Similarity}_{it} + \gamma 6\ \text{British Exports}_{it-1} + \alpha 1\ \text{Canada}_{i} + \delta 1\ \text{Charcoal}_{it} + \delta 2\ \text{Hot-Metal}_{it} + \varepsilon_{it}$$

In *Models 1-7* all continuous variables are measured as natural logarithms, which implies that parameter estimates represent contemporaneous elasticities.[25] In each model the α parameters include the constant and a fixed effect for time invariant, but nation-specific import demand determinants that are otherwise absent from the equations. The β parameters reflect the responsiveness of British trans-Atlantic pig iron exports to changes in trade costs, including transport costs, tariffs, and exchange rate effects. The γ parameters reflect the responsiveness of British exports to changes in standard import demand determinants, including domestic prices, British prices, prices in the neighbouring North American market, gross investment, an indicator of development similarities, and lagged exports. The δ parameters reflect technological discontinuities associated with the switch from charcoal to coke, and the move from stand-alone pig iron blast furnaces to integrated steel mills (that used hot pig iron, rather than re-heating cold iron).

5. Elasticities and Estimation Results

We begin by estimating *Models 1-7* by ordinary least squares (OLS). The results, including the parameter estimates for each model, robust standard errors that have been corrected for both serial correlation in the error terms and within and across panel heteroskedasticity, and an indicator of standard levels of statistical significance, are reported in Table 2-Panel A. Just as Jacks and Pendakar (2010: 750) report for British trade as a whole, from *Model 1* we can see that the unconditional correlation linking trans-Atlantic ocean freight rates to pig iron exports was small, statistically indistinguishable from zero, and *positive*.[26] This positive parameter estimate suggests that if we ignore all of the other dimensions of the transport cost-trade relationship, falling ocean freight rates were associated with falling trade volumes, not an expansion in

[25] We follow Sinha and Sinha (2000) and the minimization of Akaike Information Criteria in our adoption of the log-log specification. Indexes have been created with the minimum observed value set equal to 1.00 for the effective transport and tariff variables that have negative values over some years. Phillips-Perron unit root tests have been performed to ensure stationarity in the key variables. Sensitivity tests have been performed using levels and first differenced data (see Table 4: *Test 3* and *Test 4*).

[26] As described in the Data Appendix, the ocean freight rate series interpolates over missing years using other westbound trans-Atlantic freight rates. Up to 28 observations are lost if we use our narrowest definition for observed freight rates. Sensitivity tests have been performed using no interpolation in the freight rate series (see Table 4: *Test 5*).

trade, during the 1870-1913 period. Based on the estimation results from the remaining models, the other dimensions of this relationship clearly cannot be ignored.

The *Model 2* results reported in Table 2-Panel A reveal the extent to which the British failure literature has been correct to focus on productivity differences, technological choice and input quality, insofar as these effects manifest themselves in changes in relative output prices. When we control for standard import demand determinants in *Model 2*, we can see that the OLS relationship between ocean freight rates and trade volumes is even smaller and less statistically significant than the unconditional correlation reported for *Model 1*. However, what really stands out from *Model 2* is the size and strength of the import demand determinants' elasticities, particularly those for domestic and British output prices, gross investment and lagged exports. The estimates indicate that a 1% decrease in Canadian or US pig iron prices was associated with a 2.4% decrease in British shipments, while a 1% increase in British pig iron prices was associated with a 1.5% decrease in shipments. We can also see that a 1% increase in domestic demand (gross investment) was associated with a 0.6% increase in British exports.[27] GDP similarity has a statistically weak and surprisingly negative point estimate. And although its statistical influence strengthens in later models, other North American pig iron prices are negatively correlated to export quantities (indicating that the neighbouring market represents a substitute destination for British trade), but insignificant in *Model 2*. In general, these results continue to hold as we add control variables in *Models 3-7*, and they suggest that Britain's trans-Atlantic trade was remarkably sensitive to changes in relative prices for pig iron.

In *Model 3* trade volumes remain remarkably insensitive to ocean freight rates, although the conditional correlation is now negative, indicating that only after controlling for the impact of import demand determinants, technological discontinuities and exchange rate effects can we find any evidence that falling transport costs might have been associated with trade expansion. As we might reasonably expect among trade partners who were all strongly committed to the gold standard, exchange rate effects were also insignificant, and only the move to hot-metal and integrated steel mills during the

[27] Sensitivity tests have been performed using industrial output indexes in place of gross investment as domestic demand control variables (see Table 4: *Test 6*).

mid and late-1890s was associated with a statistically identifiable change in the pig iron trade.[28]

Model 4 includes gross tariffs as an additional control for trade costs. The OLS estimate of the sensitivity of British pig iron exports to freight rates remains small, but it is now (marginally) statistically significant. We can see that increases in North American tariffs on pig iron were strongly correlated with a reduction in British exports, such that a 1% increase in tariffs was associated with a nearly 0.58% decrease in the net tons of iron shipped. When we subtract duties imposed on iron ore and coal from the gross pig iron duties to derive the measure of effective tariff protection used in *Model 5*, we see that trade volumes remain insensitive to freight rates, but tariffs are even more strongly correlated to British pig iron shipments. A 1% increase in North American pig iron tariffs in excess of any tariffs imposed on iron ore and coal, was associated with a statistically significant 0.62% reduction in British pig iron exports.

In *Model 6* we include all costs involved in the movement of pig iron from British blast furnaces to North American consumption points when we consider gross transport costs in our import demand function. Overland rail charges and Great Lakes shipping costs associated with the movement of iron ore and coke from Marquette and Connellsville to Pittsburgh and Hamilton are subtracted from these gross transport costs to derive the effective transport cost variable included in *Model 7*. The OLS elasticity estimates on both gross and effective transport costs from these models continue to be relatively small, negative, and they lie right on the threshold of our standard level of marginal statistical significance.[29] If we were satisfied that all of the underlying assumptions required for an OLS estimation approach were met, then based on the results reported in Table 2-Panel A, we could safely conclude that transport costs may have had some weak and intermittent impact on the trans-Atlantic iron trade, but any transport cost-trade relationship must have been dwarfed by the impact of tariffs, relative output prices, and domestic demand. However, we are not prepared to settle on this conclusion

[28] Because the exchange rate volatility variable and the gold standard dummy are strongly collinear, sensitivity tests have been performed using only the gold standard dummy (see Table 4: *Test 7*).

[29] The *p-values* on the transport elasticity in *Models 6* and *7* are 0.344 and 0.086, respectively. Davis and Irwin (2007) assume a common response to output prices and all forms of trade protection. Sensitivity tests have been performed combining effective tariffs and effective transport costs into a single protection variable (see Table 4: *Test 8*). Statistical tests strongly reject the hypothesis that output price, tariff and transport cost elasticities are equal.

because in all of our models one of the key OLS assumptions - the exogeneity of the independent variables - is almost certainly violated.

Insert Table 2 Panel A and Panel B

The OLS estimates reported in Table 2-Panel A reveal that North American and British prices, transport costs and tariffs may well have had an impact on the quantity of British pig iron shipped to North America. However, as described by Irwin (2000), Jacks and Pendakar (2010), and Inwood and Keay (2012), there may be significant endogeneity problems embodied in the relationships connecting each of these three import demand determinants to trade volumes. For example, while increases in the price of pig iron in Philadelphia and Montreal may encourage trans-Atlantic trade, the resulting increase in British imports could shift domestic supply curves, subsequently driving down North American prices. This source of endogeneity, therefore, implies a potential downward bias the OLS elasticity estimates for North American prices in our import demand functions. Similarly, a downward bias may also exist among the transport cost elasticities reported in Panel A because, while an increase in transport costs may suppress trade volumes, lower trade volumes also reduce the demand for shipping services, potentially driving down transport costs.[30] Another concern is the possibility that rising North American tariffs could reduce British exports, but falling British competition could be used to justify either higher tariffs, because the policy has been so successful and therefore may be politically popular, or lower tariffs, because the policy has succeeded in its protective objectives and/or failed in its revenue objectives.

To control for each of these potential sources of endogeneity in our import demand functions, we adopt a generalized two stage least squares (2SLS) instrumental variables approach.[31] Excluded instruments for domestic prices include German iron ore

[30] Trans-Atlantic shipments of pig iron were not so large that we might expect them to affect the *global* demand for transport services, but they did represent a substantial share of the total British trade flowing through Montreal. On average between 1870-1913 pig iron accounted for over 10% of all British freight unloaded at the port of Montreal (by weight), and pig iron's share of total weight peaked in 1909 at over 25% of all British traffic. Therefore, if the human and physical capital involved in the trans-Atlantic iron trade had product or route specific attributes, endogeneity must remain a concern in our OLS estimates.

[31] Generalized 2SLS, control function and 2SLS approaches all generate identical IV parameter estimates, but because each method makes different assumptions about the underlying error structure, the reported standard errors can vary slightly. Generalized 2SLS is appropriate for use with panel data and linear estimation models. Our qualitative conclusions are not affected by the use of a control function or 2SLS approach.

and coal prices, German unskilled manufacturing wages, British long term bond yields, and domestic manufacturing productivity.[32] For transport costs our excluded instruments include the size of the British merchant fleet (number and tonnage of steam and sail vessels), Canadian fish prices, Norwegian sailors' wages, and the standard deviation in barometric pressure along the North Atlantic trade route.[33] The excluded instruments for North American tariff rates, which include German and British pig iron output levels, and the neighbouring country's production levels and tariffs, have been selected from among the factors typically used in political economy models to describe the determination of late nineteenth century trade policies.[34]

The IV results from *Models 1-7*, including the parameter estimates for each model, robust standard errors that have been corrected for both serial correlation in the error terms and within and across panel heteroskedasticity, and an indicator of standard levels of statistical significance, are reported in Table 2-Panel B. For each model we also include an indicator that endogeneity can be identified among the explanatory variables (Hausman specification tests), the instruments from the first-stage regressions have significant statistical strength (weak instrument *F* tests), and the first-stage instruments are, in fact, exogenous (Sargan over-identification tests).[35] A comparison of Panel A and Panel B reveals that for the continuous exogenous independent variables, the move to an IV approach has little quantitative and no qualitative impact. The IV estimates are slightly more elastic for British prices and slightly less elastic for lagged exports. There are only very small changes in the elasticity estimates for neighbouring North American prices, gross investment, and GDP similarities. Across all seven models the sign and significance of all of these continuous exogenous independent variables' elasticity estimates are unaffected by the introduction of controls for endogeneity.

[32] Domestic manufacturing productivity is measured as total factor productivity for all non-iron and steel manufacturing industries.
[33] These instruments closely match those employed by Jacks and Pendakar (2010). The authors thank David Jacks for providing the data (and documentation) for their construction. The use of instruments identical to those employed by Jacks and Pendakar (without lags) does not affect our qualitative conclusions.
[34] Political economy models that include these instruments as trade policy determinants can be found in Irwin (1994) or Beaulieu and Emery (2001).
[35] In *Model 1* the proportion of the British merchant fleet powered by steam has been dropped as an excluded instrument to ensure exogeneity.

When we compare the IV and OLS elasticity estimates associated with North American domestic pig iron prices, across all seven models we find that even though, as expected, the OLS estimates appear to have a small downward bias, the sign and significance of the *Own Price* elasticities is unaffected by our move to an IV approach. Falling domestic prices in the Canadian and US iron markets remain strongly and significantly correlated with falling British pig iron exports.

Because a reduction in British import competition could have encouraged either an increase or decrease in the political rewards associated with tariff protection, *a priori* we could not predict the direction of any potential bias that might exist in the OLS estimates due to endogenously determined tariffs. A comparison of Panel A and Panel B reveals that any bias must be small. Although the IV estimates do appear slightly more elastic (more negative) than the OLS estimates, in *Models 4-7* the gross and effective tariff elasticities derived from both approaches, and their standard errors, are very similar. Falling North American tariffs remain strongly and significantly correlated with rising British pig iron export volumes.

The transport cost results are a different story. In contrast to the *Own Price* and *Tariff* elasticity estimates, the OLS estimates for transport costs appear to suffer from a substantial downward bias. After using the size of the British merchant fleet, Canadian fish prices, Norwegian sailors' wages, and North Atlantic climate variables as excluded instruments to control for the possibility that higher trans-Atlantic transport costs may suppress trade, while simultaneously, lower trade volumes may reduce the demand for transport services, we find a strong and significant connection between transport costs and trade. For all models the IV transport cost elasticities are larger (more negative) and more significant than the OLS estimates. In *Models 2-4* the correlation between ocean freight rates and British pig iron shipments is large and negative, but only becomes (marginally) statistically significant after controlling for gross tariffs. In *Model 5* the sensitivity of British exports to freight rate movements is even larger than in the previous models and it is now strongly statistically distinguishable from zero. In *Model 6* we include gross transport costs, and the IV elasticity estimate is larger still (a 1% drop in gross transport costs was associated with a 1.4% increase in trade volumes) and statistical significance remains strong. From *Model 7* we can see that between 1870-1913 British trans-Atlantic pig iron exports were particularly responsive to changes in effective transport costs. Only domestic prices appear to have had a more sensitive connection to trade volumes in *Model 7*. After controlling for endogeneity, a 1% increase in the cost to move pig iron across the Atlantic, less the cost to assemble iron ore and coke within North America, was associated with a statistically significant 2.7% drop in British pig iron shipments into the US and Canada.

Insert Table 3

Of course, all of the estimates we have reported from Table 2-Panel A and Panel B represent short run, contemporaneous elasticities. Following Irwin (2000: 285) we allowed for delayed export responses by including lagged export quantities in our import demand functions. We can use the parameter estimates from these lagged export variables to calculate longer run responses to changes in tariffs and transport costs.[36] In Table 3 we report the short run import demand elasticities for transport costs and tariffs from Table 2-Panel B (and an indicator of standard levels of statistical significance), and to illustrate the extent to which trade responses became increasingly sensitive over time, we also report the long run transport and tariff elasticities. The long run elasticities for both tariffs and transport costs are nearly double the short run elasticities across all models. For *Model 7* we see that after allowing for lagged export responses, a 1% increase in effective transport costs was associated with a reduction in British pig iron shipments to North America in excess of 4.5%, while a 1% increase in effective tariffs was associated with just over a 1.2% reduction in shipments.

The IV elasticity estimates reported in Table 2-Panel B and Table 3 indicate that if we control for all import demand and trade cost determinants, if we measure all determinants of final good and raw material transport costs, and if we take account of the potential endogeneity in the transport cost-trade relationship, a strong and significant connection linking the cost to move products between distant markets and the quantity of products exchanged between these markets exists. These estimates, therefore, reaffirm the importance of transport costs in the determination of late nineteenth and early twentieth century trade volumes. This leaves us with a final question to address: does

[36] Long run elasticity = short run elasticity ÷ (1 - lagged export elasticity).

this reaffirmation tell us anything historically or economically relevant about the late nineteenth and early twentieth century trans-Atlantic iron trade?

6. The Impact on Trade Volumes: Providing Some Economic and Historical Context

A series of four simple counterfactual experiments allow us to put our econometric evidence into an appropriate and meaningful historical and economic context. In these experiments we use the IV elasticity estimates from *Model 7*, reported in Table 2-Panel B, to execute iterative simulations in which we determine the level of British trans-Atlantic pig iron exports in each year between 1870-1913 in counterfactual environments in which: there are no changes in North American tariffs (*Counterfactual # 1*); no changes in North American prices relative to British prices (*Counterfactual # 2*); no changes in westbound trans-Atlantic freight rates (*Counterfactual # 3*); and no changes in effective transport costs (*Counterfactual # 4*).

We observe actual British pig iron exports into North America rising by 31.3% between 1870-1913 (a 327% increase in shipments into Canada and a 13% decline in US shipments). In our first counterfactual we simulate British export volumes in each year with our IV elasticity estimates and all but one of the observed explanatory variables. In this counterfactual we hold US and Canadian effective tariff rates fixed at their 1870 levels, and we iterate the model forward through time using use simulated rather than observed *t-1* export quantities. The results from this experiment are depicted in Figure 6. We find that if Canadian effective tariff rates had not risen from their 1870 levels and US tariffs had not fallen, British exports still would have increased, but only by 26.7% - a 4.6 percentage point drop from the observed expansion in trade quantities. As this result suggests, trade suppression due to the maintenance of high US pig iron tariffs would have just dominated any trade promotion effects associated with keeping Canadian tariffs low.

Insert Figure 6

In our second counterfactual we again simulate British export volumes, but this time we maintain the log-difference between British pig iron prices and US and Canadian pig iron prices at their 1870 levels. British prices are allowed to evolve over our period of study as we actually observe them, but US and Canadian prices are not allowed to fall relative to the British price. Here we are following the British failure literature, which emphasizes the impact of technological choice, productivity improvements, and input quality on the British iron industry's ability to match competitors' output price reductions. The results again illustrate that those who have contributed to this literature were correct to focus on changes in relative prices. From Figure 6 we can see that if US and Canadian prices had not fallen relative to British prices, trans-Atlantic iron shipments would have been much larger than we actually observe.[37] The results from *Counterfactual # 2* indicate that the quantity of British pig iron exported into North America would have grown by 319% (288 percentage points higher than observed growth) over the 1870-1913 period if British producers had not lost their relative price advantage in the US and Canadian markets.

In our third and fourth counterfactual experiments we simulate British export volumes holding ocean freight rates fixed at their 1870 levels (*Counterfactual # 3*), and holding effective transport costs fixed at their 1870 levels (*Counterfactual # 4*). If westbound trans-Atlantic freight rates had not fallen during the 44 years after 1870, British pig iron exports would have decreased by 58%. This represents an 89 percentage point decline from the observed expansion in trans-Atlantic shipments. Clearly, falling ocean freight rates were stimulating trade during this period. However, as our elasticity estimates revealed, trans-Atlantic freight rates were not the only relevant determinant of transport costs.

When we hold all transport costs, including intra-continental raw material shipping costs, constant after 1870, the counterfactual trade volume effects very nearly match those associated with fixed relative output prices in *Counterfactual # 2*. In our fourth counterfactual we do not allow inter or intra-continental freight rates, railway charges, brokerage fees, wharfage, or insurance to vary from their 1870 levels. In Figure 6 we can see that this experiment predicts substantial increases in British trade volumes – an increase in British exports into the US and Canada of 304%, or 273 percentage points higher than the observed growth in trade. There is, of course, one caveat we must keep in

[37] By maintaining relative pig iron prices at their 1870 levels, we are not only imposing a counterfactual *Own Price* variable on our simulations, but *Other North American Prices* are also fixed over our period of study. Therefore, for example, British exports into Canada would have grown faster than observed if Canada's relative pig iron prices had not fallen, but if US prices also did not fall, then Canada would have looked like a relatively less desirable export market, so there would have been coincident downward pressure on British exports into Canada. The trade volumes predicted by *Counterfactual # 2* reflect the net impact of these conflicting relative output price effects.

mind when assessing the results from these experiments. Each counterfactual simulation varies only one determinant, while holding all else constant. Therefore, for example, in *Counterfactual # 4* British and North American pig iron prices are not allowed to adjust to the dramatic restructuring of the trans-Atlantic iron markets implied by the results. If we were to take the predictions of this experiment at face value, we would be implicitly assuming perfectly elastic supply curves in the US, Canada and Britain, at each point in time throughout the 1870-1913 period. Clearly, this assumption does not reflect the economic realities of the late nineteenth and early twentieth century iron markets. Despite this limitation, the experiment is still useful in that it clearly illustrates the relative economic and historical importance of the trade effects implied by our transport cost, tariff, and output price elasticity estimates.

7. Conclusions

Between 1870-1913 global trade volumes expanded and ocean freight rates fell. It is often taken for granted that the movement in these two economic variables must be causally linked. However, recent empirical trade literature has called into question the importance of freight rates in promoting trade in a contemporary context, and efforts to confirm the presence of a freight rate-trade connection during the late nineteenth and early twentieth centuries has produced, at best, weak support for the proposition. An empirical investigation into the complex relationship between transport costs and trade volumes must consider the multi-dimensional nature of these costs. It is not ocean freight rates alone that affect the incentive to trade between geographically distant markets. Other transport costs, including those paid during the assembly of raw material inputs, must also be incorporated into the analysis. A scarcity of detailed evidence on transport costs and trade quantities from the 1870-1913 globalization period necessitates the adoption of a finely detailed product and route-specific case study to identify the presence and strength of the transport cost-trade link.

In this paper we use newly compiled evidence on westbound trans-Atlantic transport costs for pig iron and intra-continental transport costs for iron ore and coke to estimate short and long run elasticities derived from a series of import demand functions. These estimates include explicit controls for endogeneity in the transport cost, tariff and domestic price connections to trade. We find that changes in relative output prices, changes in tariff rates and changes in domestic demand were important determinants of the quantity of pig iron shipped from the UK to North America between 1870-1913, but ocean freight rates and effective transport costs also had strong and significant effects. Our elasticity estimates reaffirm the importance of transport costs in the determination of trade volumes. A series of four counterfactual experiments illustrate the underappreciated impact that rising effective transport costs had on the collapse of the British trans-Atlantic iron trade after 1870. Changing transport costs affect trade volumes, but all dimensions of these costs must be considered, and the endogeneity inherent in the transport cost-trade relationship must be accounted for if we are to empirically identify and assess the strength of the connection.

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9. Figures and Tables

Figure 1a: Pig Iron Production

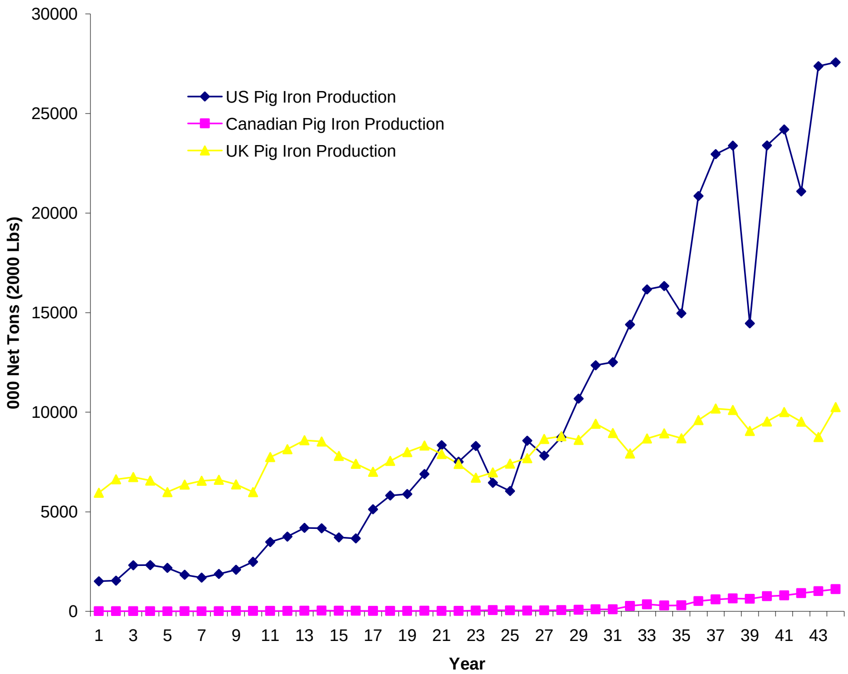

Figure 1b: Per Capita Pig Iron Production

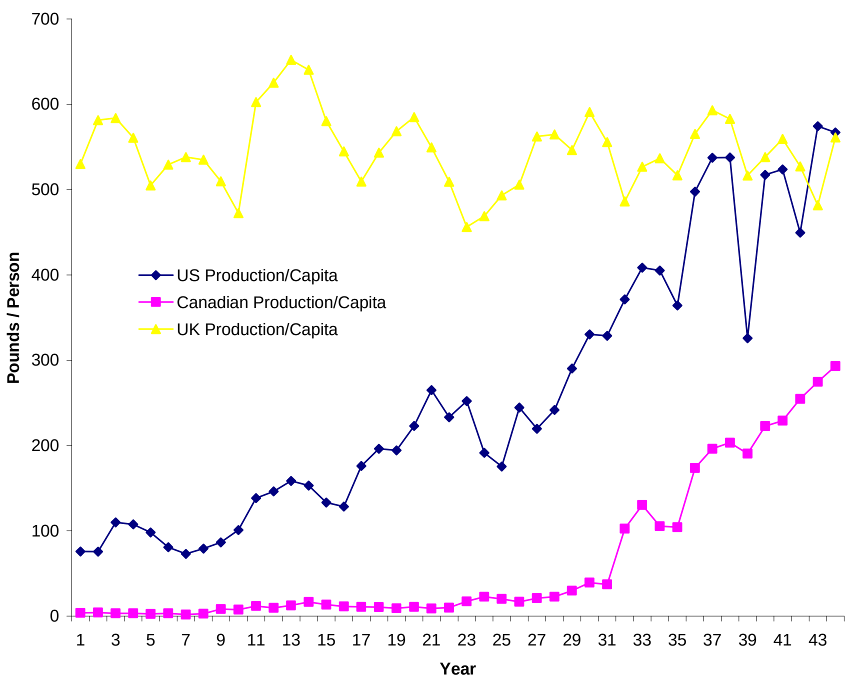

Figure 2a: UK Pig Iron Exports into North America

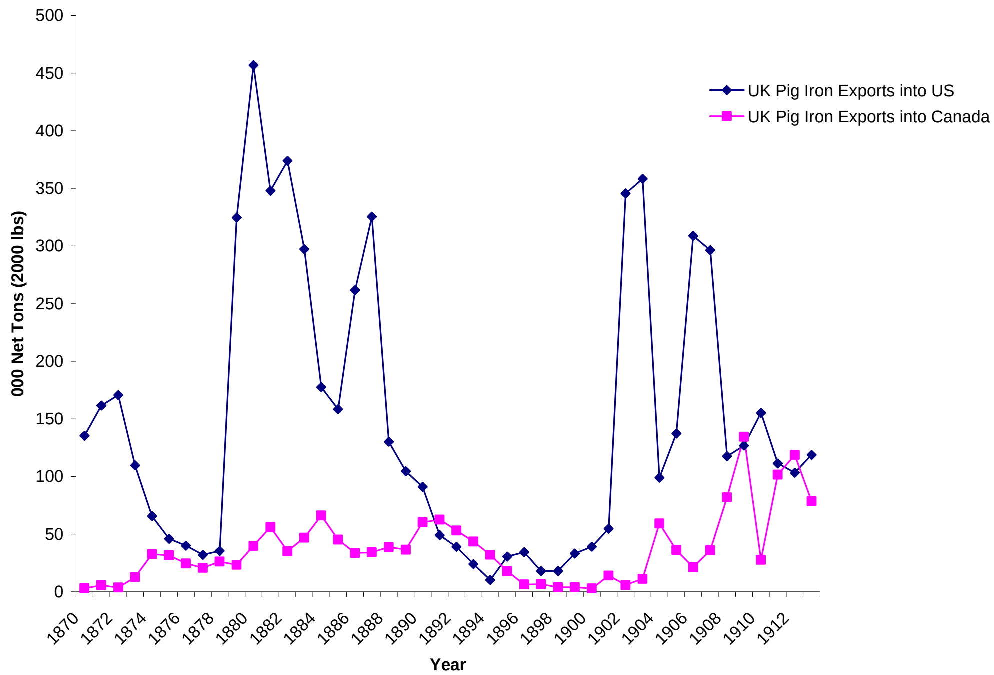

Figure 2b: UK Share of North American Pig Iron Markets

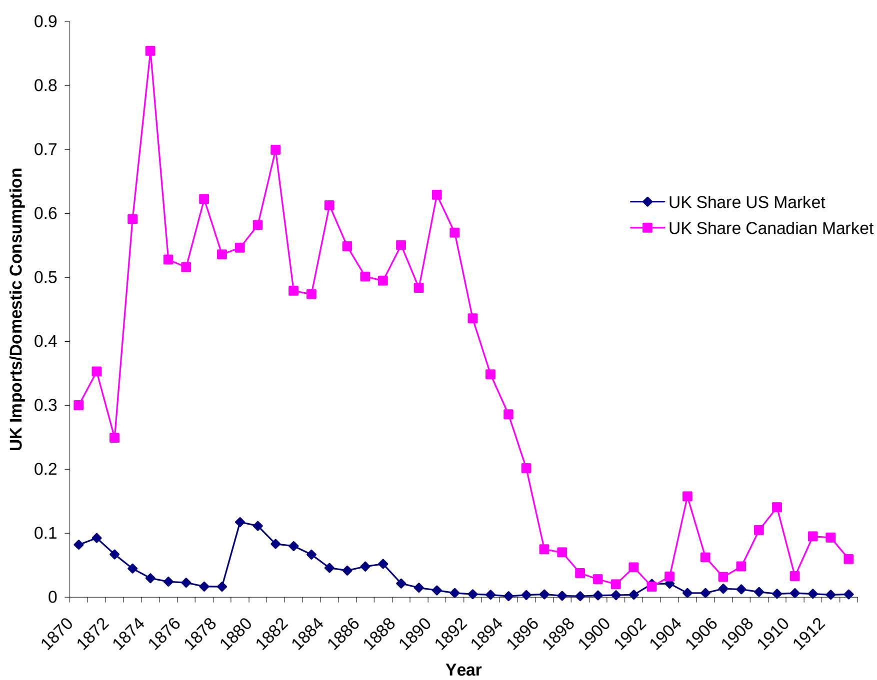

Figure 3a: Westbound Pig Iron Ocean Freight Rates
(Montreal - NYC Comparison)

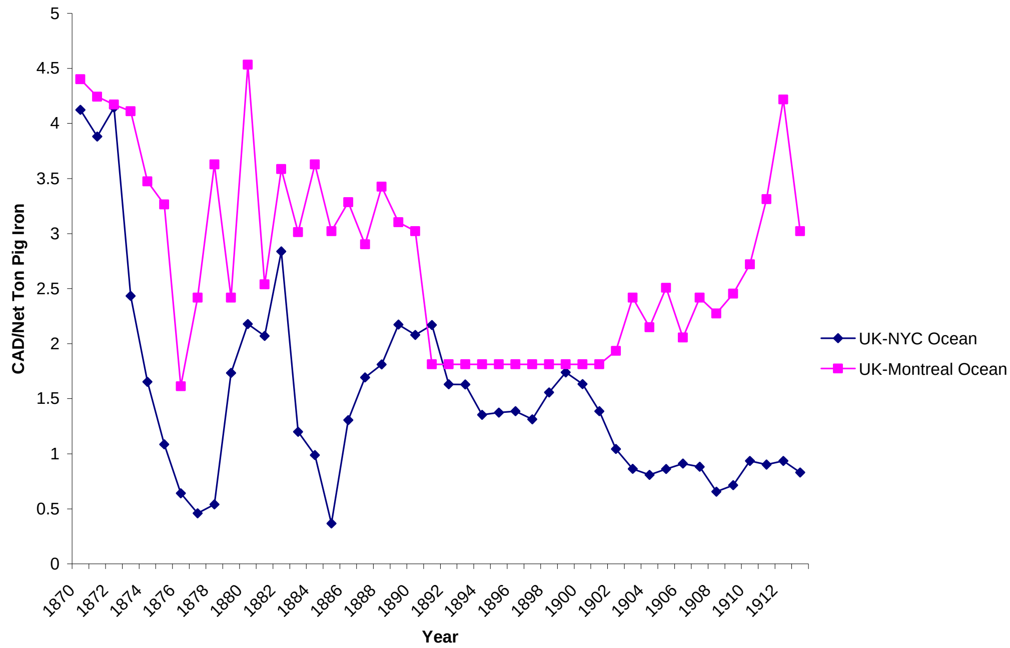

Figure 3b: Westbound Pig Iron Total Transport Costs to Market
(Hamilton - Pittsburgh Comparison)

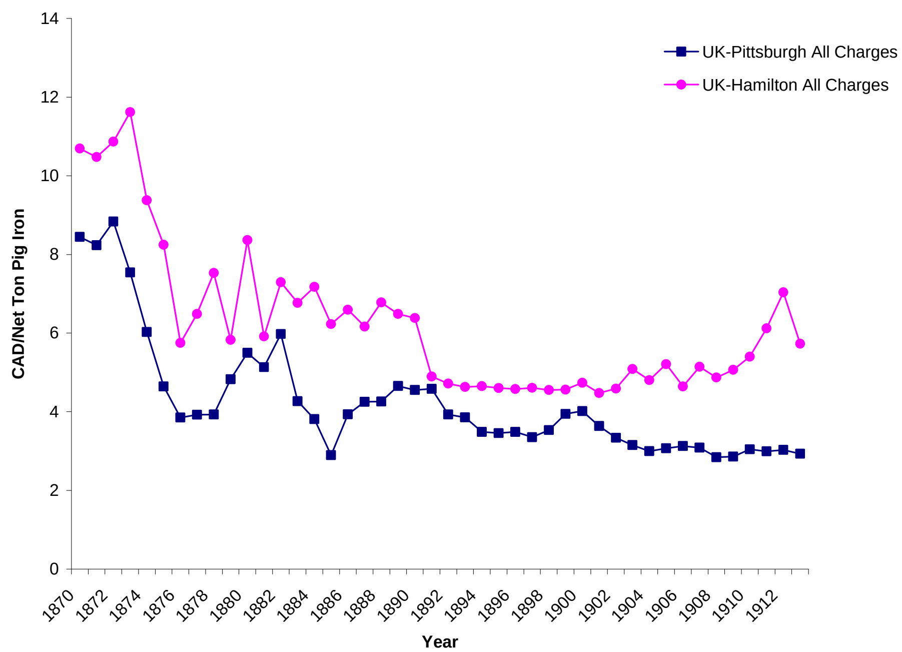

Figure 3c: North American Effective Transport Protection for Pig Iron

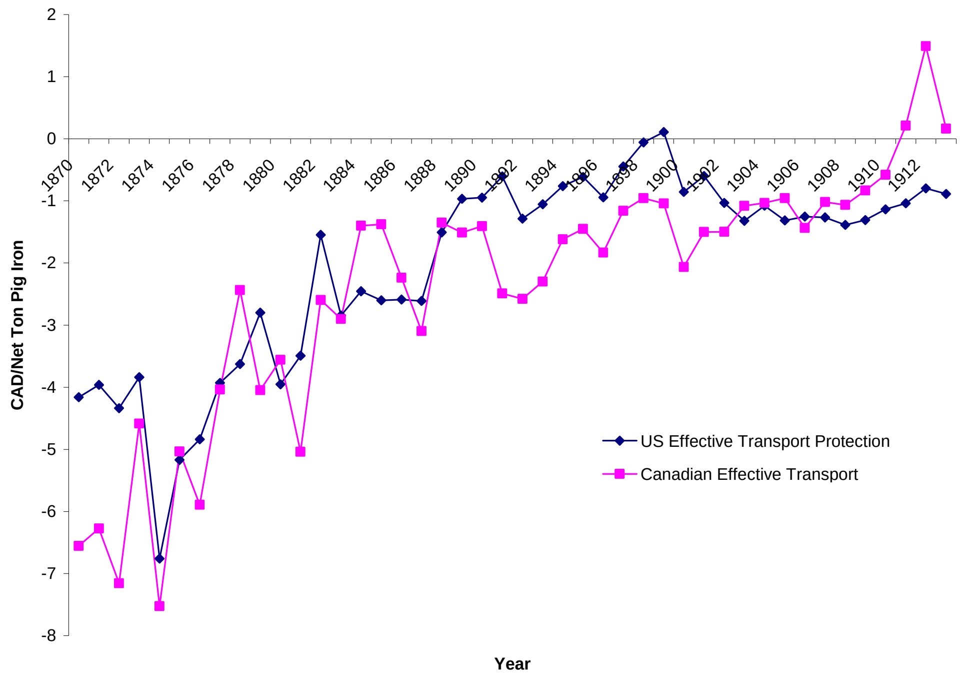

Figure 4: North American Effective Tariff Protection for Pig Iron

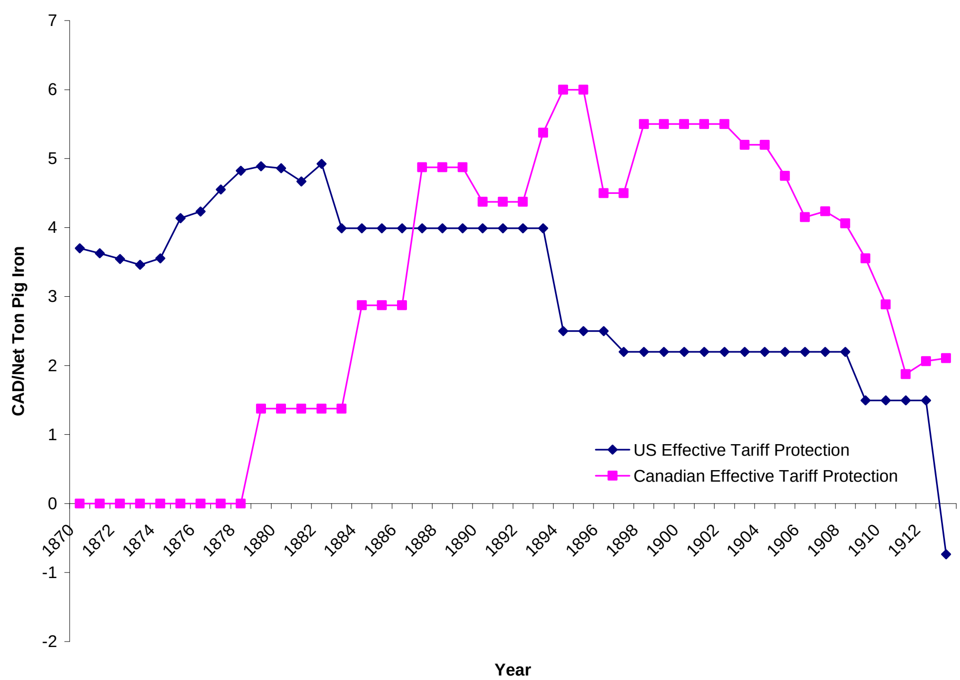

Figure 5: North American Ad Valorem Effective Protection for Pig Iron

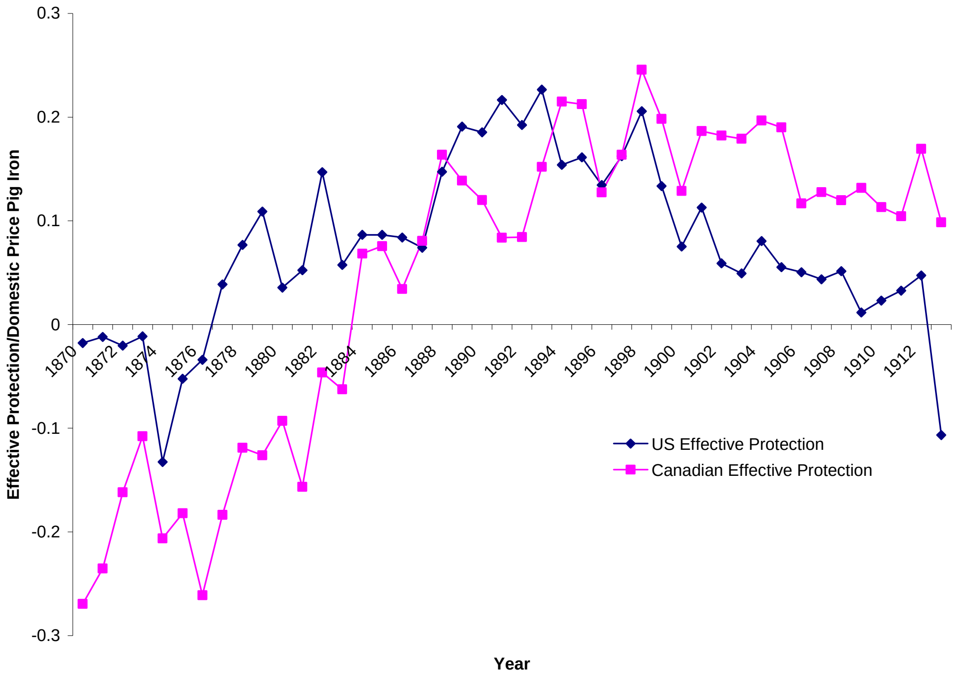

Figure 6: Counterfactual British Pig Iron Exports into North America

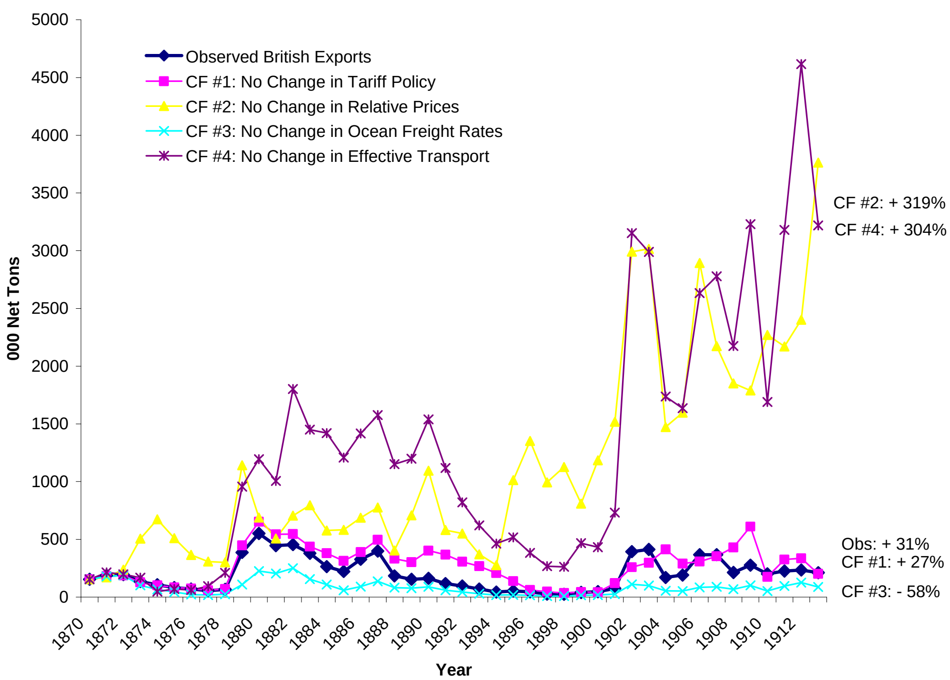

Table 1: Summary Statistics

	Canada			US		
	Mean	Std Dev	% Δ	Mean	Std Dev	% Δ
Production and Trade:						
Domestic Production	209.5	316.0	0.119	9798.4	7954.7	0.068
Domestic Exports	3.4	7.5	0.041	53.6	78.9	0.125
British Imports	37.2	30.6	0.076	147.1	121.8	-0.003
British Market Share	0.322	0.245	-0.038	0.028	0.032	-0.069
Protection:						
Ocean Freight Rate	2.76	0.86	-0.009	1.52	0.89	-0.037
Total Transport	6.27	1.90	-0.015	4.26	1.52	-0.025
Effective Transport	-2.42	2.04	0.016	-2.04	1.57	0.014
Gross Tariff	3.33	2.13	0.002	4.61	1.53	-0.021
Effective Tariff	3.12	2.10	0.013	3.14	1.23	-0.022
Effective Protection	0.70	3.77	0.043	1.09	1.35	0.007
Exchange Rate:						
Exchange Rate Volatility	0.003	0.004	-0.087	0.012	0.018	-0.107
Import Demand:						
Own Price	24.32	6.70	-0.005	23.35	7.41	-0.014
British Price	11.21	2.99	0.006	11.21	2.99	0.006
Gross Investment	1738.8	1609.8	0.056	6138.6	3579.4	0.049
GDP Similarity	0.069	0.018	0.020	0.239	0.012	-0.003

Note: Quantities = 000s net tons; prices, rates, tariffs = CAD/net ton; values = 000s CAD; % Δ = average annual log difference, 1870-1913. Variable definitions, descriptions, construction, sources provided in Data Appendix: http://www.econ.queensu.ca/files/other/irondataapp.pdf

Table 2: North American Import Demand Functions

	Panel A: OLS Independent Variable = British Pig Iron Exports to North America (Net Tons)						
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Transport:							
Ocean	0.248	0.075	-0.143	**-0.220***	**-0.225***		
	(0.198)	(0.132)	(0.142)	(0.123)	(0.123)		
Ocean + Other Freight						-0.340	
						(0.355)	
Effective Transport							**-0.837***
							(0.481)
Tariff:							
Gross Tariff				**-0.575*****			
				(0.170)			
Effective Tariff					**-0.624*****	**-0.630*****	**-0.550*****
					(0.176)	(0.183)	(0.165)
Exchange Rate:							
Volatility			0.225	0.185	0.214	0.213	0.176
			(0.208)	(0.187)	(0.184)	(0.187)	(0.187)
Gold Standard			-0.003	0.087	0.148	0.031	0.196
			(0.553)	(0.529)	(0.512)	(0.510)	(0.511)
Import Demand:							
Own Price		**2.423*****	**2.454*****	**3.032*****	**3.071*****	**3.075*****	**2.848*****
		(0.592)	(0.611)	(0.588)	(0.602)	(0.639)	(0.564)
UK Price		**-1.510*****	**-1.225****	**-1.484*****	**-1.527*****	**-1.535*****	**-1.435*****
		(0.493)	(0.533)	(0.550)	(0.543)	(0.551)	(0.531)
Other N. Amer. Price		-0.410	-0.705	**-0.957***	**-1.027****	**-1.047***	**-1.307*****
		(0.601)	(0.558)	(0.532)	(0.516)	(0.528)	(0.488)
Gross Investment		**0.608*****	**1.218*****	**0.978*****	**0.964*****	**0.926*****	**1.072*****
		(0.131)	(0.242)	(0.234)	(0.228)	(0.226)	(0.255)
GDP Similarity		-0.339	**-1.048***	-0.350	-0.068	-0.090	-0.318
		(0.438)	(0.547)	(0.611)	(0.611)	(0.630)	(0.613)
Lagged Trade Volume		**0.572*****	**0.587*****	**0.560*****	**0.523*****	**0.530*****	**0.515*****
		(0.093)	(0.091)	(0.091)	(0.093)	(0.092)	(0.095)
Technology:							
Charcoal-to-Coke			-0.109	**-0.628****	**-0.696****	**-0.602****	**-0.843*****
			(0.284)	(0.276)	(0.303)	(0.301)	(0.297)
Cold-to-Hot Metal			**-0.681*****	**-0.805*****	**-0.641*****	**-0.601*****	**-0.600*****
			(0.225)	(0.217)	(0.214)	(0.225)	(0.201)
Fixed Effects:							
Canada	**-1.638*****	-0.723	-0.430	-0.469	0.179	0.065	-0.137
	(0.238)	(0.637)	(0.699)	(0.639)	(0.696)	(0.733)	(0.675)
Constant	**2.668*****	-1.264	-0.593	0.187	1.548	1.591	2.852
	(0.258)	(1.756)	(2.236)	(2.232)	(2.287)	(2.341)	(2.250)
N	88	86	86	86	86	86	86
R^2	0.369	0.824	0.844	0.856	0.860	0.858	0.860

Note: Annual data for Canada and US covering years 1870-1913. All variables measured in natural logarithms. ***, **, * indicate statistical significance with 99%, 95%, 90% confidence. Robust standard errors reported in parentheses. Variable definitions, descriptions, construction, sources provided in Data Appendix: www.econ.queensu.ca/files/other/irondataapp.pdf

	Panel B: IV Independent Variable = British Pig Iron Exports to North America (Net Tons)						
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Transport:							
Ocean	0.011 (0.379)	-0.351 (0.309)	-0.353 (0.294)	**-0.442*** (0.254)	**-0.551**** (0.263)		
Ocean + Other Freight						**-1.357*** (0.731)	
Effective Transport							**-2.689***** (0.938)
Tariff:							
Gross Tariff				**-0.853***** (0.328)			
Effective Tariff					**-0.941***** (0.317)	**-1.116***** (0.369)	**-0.724**** (0.306)
Exchange Rate:							
Volatility			0.100 (0.183)	0.069 (0.173)	0.115 (0.171)	0.136 (0.177)	0.074 (0.173)
Gold Standard			-0.247 (0.482)	-0.054 (0.457)	0.062 (0.464)	-0.254 (0.472)	0.433 (0.499)
Import Demand:							
Own Price		**3.818***** (0.930)	**3.802***** (0.973)	**4.386***** (0.873)	**4.582***** (0.885)	**5.013***** (1.049)	**3.466***** (0.824)
UK Price		**-2.369***** (0.663)	**-1.867***** (0.667)	**-2.117***** (0.621)	**-2.229***** (0.629)	**-2.394***** (0.674)	**-1.690***** (0.629)
Other N. Amer. Price		-0.387 (0.531)	**-0.912*** (0.496)	**-1.232**** (0.497)	**-1.302***** (0.500)	**-1.283**** (0.516)	**-1.970***** (0.532)
Gross Investment		**0.793***** (0.189)	**1.393***** (0.317)	**1.004***** (0.325)	**1.009***** (0.319)	**0.885***** (0.326)	**1.338***** (0.350)
GDP Similarity		-0.287 (0.508)	-1.068 (0.680)	-0.021 (0.764)	0.453 (0.828)	0.729 (0.914)	-0.204 (0.805)
Lagged Trade Volume		**0.485***** (0.090)	**0.490***** (0.096)	**0.470***** (0.087)	**0.407***** (0.093)	**0.405***** (0.097)	**0.415***** (0.092)
Technology:							
Charcoal-to-Coke			-0.189 (0.320)	**-0.947**** (0.427)	**-1.085**** (0.434)	**-0.926**** (0.428)	**-1.601***** (0.502)
Cold-to-Hot Metal			**-0.841***** (0.283)	**-1.001***** (0.269)	**-0.812***** (0.260)	**-0.822***** (0.278)	**-0.748***** (0.238)
Fixed Effects:							
Canada	**-1.505***** (0.304)	-0.543 (0.689)	-0.510 (0.737)	-0.524 (0.699)	0.581 (0.778)	0.742 (0.877)	0.008 (0.668)
Constant	**2.412***** (0.436)	**-3.477**** (1.770)	-2.758 (2.248)	-1.205 (1.997)	0.451 (2.162)	-0.033 (2.346)	**4.772**** (2.307)
N	88	86	86	86	86	86	86
R^2	0.361	0.799	0.831	0.845	0.845	0.837	0.841
Hausman	✗	✓	✓	✓	✓	✓	✓
Weak Instrument	✓	✓	✓	✓	✓	✓	✓
Sargan	✓	✓	✓	✓	✓	✓	✓

Note: 2-stage generalized least squares used in IV estimation (Stata Command *xtivreg*). Hausman specification tests identify the presence of endogeneity. Weak instrument tests identify jointly insignificant instruments. Sargan over-identification tests identify instrument exogeneity. Excluded instruments *Transport* = number British steam vessels, number British sail vessels, total British tonnage powered by steam, Canadian fish prices, Norwegian sailors' wages, standard deviation in North Atlantic barometric pressure. Excluded instruments *Tariff* = other North American pig iron duties, other North American pig iron output, British and German pig iron output. Excluded instruments *Own Price* = German unskilled manufacturing wages, German iron ore and coal prices, British long term bond yields, domestic non-iron and steel manufacturing TFP.

Table 3: Short and Long Run Transport and Tariff Elasticities

	Transport		Tariff	
	Short Run	Long Run	Short Run	Long Run
North America:				
Model 1	0.011			
Model 2	-0.351	-0.680		
Model 3	-0.353	-0.692		
Model 4	**-0.442***	**-0.834***	**-0.853*****	**-1.609*****
Model 5	**-0.551****	**-0.929****	**-0.941*****	**-1.586*****
Model 6	**-1.357***	**-2.282***	**-1.116*****	**-1.877*****
Model 7	**-2.689*****	**-4.593*****	**-0.724****	**-1.237****

Note: Elasticities derived from IV parameter estimates, Table 2-Panel B. *Model 1 - 7* described in text. *Short Run Tariff Elasticity =* $\beta 2$*(Tariff); Short Run Transport Elasticity =* $\beta 1$*(Transport); Long Run Tariff Elasticity =* $\beta 2 \div (1 - \gamma 6$ *(Lagged Trade Volume)); Long Run Transport Elasticity =* $\beta 1 \div (1 - \gamma 6)$. ***, **, * indicate statistical significance with 99%, 95%, 90% confidence.

Table 4: Sensitivity Testing

	Model 7: IV Independent Variable = British Pig Iron Exports to North America (Net Tons)								
	Table 2-Panel B: Model 7	Test 1: Gross US Tariffs	Test 2: Alt. Cold-to-Hot Metal	Test 3: Levels	Test 4: First Differences	Test 5: No Interpolation	Test 6: Industrial Q	Test 7: Drop Exch. Rate Volatility	Test 8: Combine Trans-Tariff
Transport:									
Effective Transport	**-2.689*** **	**-2.678*** **	**-1.837** **	**-3.182** **	**-0.905* **	**-2.752** **	**-2.536** **	**-2.585*** **	
	(0.938)	(0.935)	(0.894)	(1.593)	(0.496)	(1.360)	(1.009)	(0.951)	
Tariff:									
Effective Tariff	**-0.724** **	**-0.500** **	**-0.624** **	-1.245	-0.064	**-0.785** **	**-1.163*** **	**-0.754** **	
	(0.306)	(0.201)	(0.292)	(1.313)	(0.766)	(0.369)	(0.302)	(0.305)	
Protection:									
Combined Tariff-Transport									**-3.395*** **
									(0.927)
Exchange Rate:									
Volatility	0.074	0.037	0.076	-312.2	0.008	0.311	-0.007		0.021
	(0.173)	(0.174)	(0.168)	(278.5)	(0.266)	(0.223)	(0.182)		(0.177)
Gold Standard	0.433	0.401	0.523	8.819	0.124	**0.984* **	0.647	0.314	0.296
	(0.499)	(0.496)	(0.491)	(11.164)	(0.184)	(0.540)	(0.534)	(0.436)	(0.488)
Import Demand:									
Own Price	**3.466*** **	**3.482*** **	**3.063*** **	**2.934*** **	**3.629*** **	**1.872* **	**3.866*** **	**3.640*** **	**3.702*** **
	(0.824)	(0.818)	(0.815)	(0.870)	(1.181)	(1.039)	(0.909)	(0.704)	(0.786)
UK Price	**-1.690*** **	**-1.645*** **	**-1.561** **	**-1.994** **	-1.119	-0.328	**-1.953*** **	**-1.788*** **	**-1.624*** **
	(0.629)	(0.620)	(0.644)	(0.897)	(0.916)	(0.757)	(0.718)	(0.583)	(0.611)
Other N.A. Price	**-1.970*** **	**-1.982*** **	**-1.582*** **	**-1.555*** **	**-2.405*** **	**-1.707** **	**-1.968*** **	**-1.953*** **	**-2.272*** **
	(0.532)	(0.529)	(0.494)	(0.391)	(0.742)	(0.672)	(0.578)	(0.531)	(0.588)
Domestic Demand	**1.338*** **	**1.325*** **	**1.138*** **	13.268	0.590	**1.328*** **	**1.042*** **	**1.260*** **	**1.073*** **
	(0.350)	(0.348)	(0.383)	(9.661)	(0.498)	(0.516)	(0.398)	(0.338)	(0.301)
GDP Similarity	-0.204	-0.251	0.030	**190.2*** **	**4.765* **	-0.985	**1.998*** **	-0.055	0.405
	(0.805)	(0.780)	(0.768)	(64.732)	(2.575)	(1.376)	(0.578)	(0.769)	(0.794)
Lagged Trade Volume	**0.415*** **	**0.411*** **	**0.330*** **	0.125	-0.048	**0.445*** **	**0.391*** **	**0.399*** **	**0.397*** **
	(0.092)	(0.092)	(0.102)	(0.138)	(0.106)	(0.121)	(0.101)	(0.082)	(0.095)
Technology:									
Charcoal-to-Coke	**-1.601*** **	**-1.580*** **	**-1.301*** **	**-17.286*** **	0.241	**-1.848*** **	**-1.590*** **	**-1.595*** **	**-1.984*** **
	(0.502)	(0.490)	(0.475)	(5.792)	(0.264)	(0.575)	(0.541)	(0.499)	(0.601)
Cold-to-Hot Metal	**-0.748*** **	**-0.744*** **	**-0.746*** **	1.364	-0.007	**-1.135*** **	**-0.588** **	**-0.729*** **	**-0.674*** **
	(0.238)	(0.238)	(0.288)	(3.668)	(0.133)	(0.340)	(0.253)	(0.238)	(0.227)
Fixed Effects:									
Canada	0.008	-0.307	-0.186	8.953	-0.144	-0.782	0.951	0.009	0.208
	(0.668)	(0.633)	(0.661)	(15.215)	(0.151)	(1.199)	(0.685)	(0.664)	(0.694)
Constant	**4.772** **	**3.737* **	**4.334* **	-46.226	-0.065	**5.570* **	**5.487** **	**4.329** **	**5.468** **
	(2.307)	(2.112)	(0.2.231)	(28.707)	(0.171)	(2.897)	(2.516)	(2.093)	(2.480)
N	86	86	86	86	86	58	86	86	86
R^2	0.841	0.842	0.851	0.772	0.230	0.874	0.817	0.841	0.834
Hausman	✓	✓	✓	✓	✓	✓	✓	✓	✓
Weak Instrument	✓	✓	✓	✓	✗	✓	✓	✓	✓
Sargan	✓	✓	✓	✓	✓	✓	✓	✓	✓

Note: Test 1 drops US input tariffs; Test 2 controls for early (1892) and late (1902) steel mills separately; Test 3 drops log-log specification; Test 4 uses first differenced data; Test 5 drops interpolated freight rates; Test 6 uses industrial output index for domestic demand; Test 7 drops exchange rate volatility variable; Test 8 forces transport and tariff elasticities to be equal.