Transport Costs, Trade Policy and Industrial Development: Iron and Steel in a Small Open Economy, 1870-1913†

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Abstract

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Near the end of the nineteenth century the Canadian primary iron and steel industry experienced a rapid technological transformation, which was followed closely by a dramatic expansion in output, market share and productivity. Was this a case of industrial development being fostered by government policy? Was it simply due to exogenous market expansion as the Canadian economy expanded westward and demand for iron and steel increased throughout the Atlantic Economy? Or perhaps the discovery of new iron ores in remote regions of Canada provided a new raw material cost advantage to local producers? We argue that the expansion of the domestic market and changes in input markets may have promoted output growth, but they were not sufficient conditions for the industrial development we observe. Changes in the effective trade and transportation protection enjoyed by primary iron and steel producers triggered entry and investment in new, technologically advanced blast furnaces capable of accommodating rapid increases in output. The argument builds on a clarification of the timing of investments, government policy and the supply of raw materials in Canada; new information on westbound trans-Atlantic freight rates, intra-continental transport costs, and furnace specific micro-data; and an explicit acknowledgment of the endogeneity of firms' entry and production decisions, and government's policy decisions.
Introduction

There is nothing beautiful about pig iron. Short, squat bars or flattened slabs, dull grey and pock-marked – pig iron is as ugly as its name suggests. Despite its lack of visual appeal, for those interested in long run industrial development, a nation's ability to cheaply and efficiently produce this vital intermediate input has become synonymous with the ability to generate persistent, intensive economic growth. During the late nineteenth and early twentieth centuries, pig iron was a key input used in the production of iron and steel building materials, capital and transportation equipment, machinery, and infrastructure. To produce this product in the face of more developed international competition, a nation needed to profitably build and operate large, technologically advanced factories employing considerable quantities of physical and human capital.

Like many other nations belonging to the "Atlantic Economy", Canada enjoyed industrial success and rapid economic growth during the 1870-1913 period. Although the source of this expansion is typically associated with small, rural, resource intensive production (Inwood and Keay 2010), not all Canadian industrial enterprises fit this stereotype. Like international competitors located in the United States and Britain, Canada also developed a competitive primary iron and steel industry during this period that was able to supply virtually the entire domestic market by the turn of the twentieth century, using modern and efficient blast furnaces.

The central objective of this paper is to document the connections linking changes in transportation costs, trade policy, domestic and international demand, and supply conditions, to the technological transformation and growth of the Canadian primary iron and steel industry. We are particularly interested in the impact that government policy had on the pace and pattern of industrial development in Canada’s small, open economy. In pursuit of this objective we present newly constructed annual data series covering the years 1870-1913 for: west-bound, trans-Atlantic ocean freight rates from Liverpool to Montreal QC; east-bound Great Lake freight rates from Marquette MI to Buffalo NY; railway shipping costs from Montreal, Pittsburgh PA, and Connelsville PA to Hamilton ON; nominal Canadian bounty and tariff rates on pig iron and coke; Canadian, British and US pig iron output and input prices; and micro-data on Canadian pig iron output,
employment and productivity, by individual blast furnace.\textsuperscript{1} We use these data with an adapted version of the partial equilibrium demand and supply model that was developed by Grossman (1986), and used by Davis and Irwin (2009) and Naknoi (2010), to investigate the forces underlying the early expansion of the US pig iron industry. A basic version of our model provides us with a framework for the estimation of the sensitivity of Canadian producers to changing conditions within their domestic and international markets, input supply and marginal cost shocks, falling transportation costs, and changes in their effective tariff protection. We employ a series of exogenous instruments in our estimation to explicitly account for the endogenous connections among these determinants of the demand and supply of Canadian pig iron.

We find that the relationships linking pig iron production to domestic and international demand, transport costs, supply conditions and tariff protection were complex and fluid during the 1870-1913 period. In general, capital costs, raw material costs, cumulative output and international demand appear to have had only a weak connection to firms' production decisions. Because reductions in water and rail transport costs affect both input prices and the price of imported pig iron, the net effect of changing transport costs on Canadian pig iron production also seems to have been weak and variable throughout our period of study. However, models using linear splines and tests for parameter stability indicate that at different points through our period of study trade policy, domestic demand and labour costs had unique and distinct connections to aggregate production levels. We argue that during the 1880s and early 1890s the Canadian government's commitment to the provision and maintenance of tariff protection was positively related to domestic output levels, but this relationship weakened as domestic demand and labour costs came to play a more important role through the 1890s and early 1900s.

The results from jointly estimated Heckman selection models that use information on the entry and exit of blast furnaces and furnace-specific output figures, reinforces our view that tariff protection introduced in 1879 and 1887 encouraged entry and turn-over, promoting a technological transformation of the Canadian industry from small, rural,

\textsuperscript{1} A complete description of the construction, composition and sources for all data series used in this paper is available in a Data Appendix: http://qed.econ.queensu.ca/faculty/keayi/datalinks/irondataapp.pdf
charcoal fuelled blast furnaces to larger, modern, coke burning furnaces. After 1890, expanding domestic demand and falling labour costs fostered output expansion, but only after irreversible investments in new, technologically advanced establishments had been undertaken. The net effect of these changes in the domestic economic environment was rapid output growth, increasing market share, and eventually improved productivity for the primary iron and steel industry. In our Canadian case study, it appears that trade policy was an important trigger for the investment decisions that embodied technological and industrial development, eventually facilitating the exploitation of favourable domestic and international market conditions that sprang up around the turn of the twentieth century.

The Development of Iron and Steel in a Small Open Economy

Given the transformative expansion that occurred among many of the participants in the Atlantic Economy during the last decades of the nineteenth century, it is not surprising to find that there has been an enormous research effort directed towards understanding the causes and consequences of differential performance across nations and industries during this period (O'Rourke and Williamson 1999). Substantial bodies of empirical and qualitative literature document the effect of declining ocean freight rates (Harley 1980, 1988, 1989), expanding railway networks (Fogel 1964, Hawke and Higgins 1981, Lewis 1981, Norrie 1974), resource discoveries (Donald 1915, Prentice 2010, Wright 1990), and changing trade policies (Ashworth 1962, Foreman-Peck 1983, Harley 1992, Irwin 2000, Irwin and Temin 2001, Taussig 1931) on industrial development after 1870. Because iron and steel industries were large and influential technological leaders, they have been used in a wide range of case studies that have probed the impact of market expansion and the endogenous nature of technological change stemming from changes in transportation costs and tariffs (Allen 1977, 1979, Burn 1961, Davis and Irwin 2009, Evans and Ryden 2005, Inwood 1987, Naknoi 2010, Temin 1964, Warren 1970, 1973). Despite the volume of evidence available, remarkably few studies bring together these disparate literatures by explicitly acknowledging the interdependence and endogeneity of market expansion, land and ocean transport costs,
trade policy, and industrial development. The late nineteenth and early twentieth century economic environment in Canada presents us with a unique opportunity to investigate the impact that resource discoveries, international and domestic market expansion, falling transport costs, and discontinuous changes in tariff policy had on the technological transformation (and rapid growth) of a primary iron and steel industry in a small open economy.

At the turn of the twentieth century, expanding ore exports from Newfoundland and new iron ore discoveries in northern Ontario provided increasing supplies of domestic raw materials (Donald 1915, Inwood 1983 and 1987). At exactly this time, a boom in Canadian immigration levels, western settlement, and infrastructure building swept incomes, investment and productivity growth upwards at an unprecedented rate (Bertram 1973, Chambers and Gordon 1966, Green and Urquhart 1987, Inwood and Stengos 1991). Of course, the highly mobile labour associated with the Canadian "wheat boom" was not new. Beginning in the 1870s and accelerating through the 1880s and 1890s, internal and international migration contributed not only to the growth of the western provinces, but cities in Ontario, Quebec and the Maritime provinces also absorbed large numbers of new labour market entrants (Drummond 1987, Green and Green 1993, Green and MacKinnon 2001). Transportation networks were also undergoing significant change in Canada during the post-1870 era. Railways were built connecting Canadian cities to each other, to US markets and to port facilities. Ocean and Great Lake freight rates, and the myriad of port charges, insurance costs and miscellaneous shipping fees were also continuing their technology-driven declines (Cruikshank 1987, Fishlow 1966, Laurent 1983, Williamson 1977). Like many of the Atlantic Economies, Canadian trade policy was restructured and refocused towards protectionism during this period. Under the "National Policy" in 1879 and the "Tupper Tariffs" in 1887, effective protection rates, particularly for primary iron and steel products, rose sharply, while trade policy and the possibility of reciprocity with the United States played an important role in Federal elections fought in 1878, 1887, 1896 and 1911 (Beaulieu and Emery 2001, Dales 1966, 1979, Forster 1986, McDiarmid 1949). Clearly, the years between 1870-1913 embodied a significant restructuring of the
Canadian economic environment, and iron and steel mills were by no means divorced from these changes.

Immediately following the confederation of the Canadian provinces in 1867, over half of all domestic consumption of pig iron was supplied by foreign producers, and local production levels were declining steadily (Inwood 1986a, 1986b, 1992). Pig iron smelted in Quebec with traditional charcoal fuels was unable to compete with increasingly inexpensive British imports, Nova Scotia's solitary coke furnace was intermittently bankrupt throughout the 1870s and 1880s because of inadequate supplies of iron ore and coal, and even in Ontario, the emerging centre of industrial power in Canada, there was no pig iron production until the 1890s. However, by 1900 new, modern and technologically advanced blast furnaces had been blown in at Hamilton, Deseronto and Midland in Ontario, and Pictou and Sydney in Nova Scotia. On the eve of Canada's entry into World War 1, steel production was rapidly expanding at the Hamilton and Sault Ste. Marie blast furnaces, accounting for just over 50% of total primary iron and steel production, domestic pig iron production was 120 times what it had been in 1870 and 50 times higher than 1890 levels, and imports accounted for less than 10% of Canadian pig iron consumption (Donald 1915, Inwood 1987). Aggregate production and experience were accumulating rapidly and the industry had been technologically transformed, with much of the industry turn-over, output growth and improved competitive performance accomplished well before the turn of the twentieth century. It is the chronological coincidence of this transformation of the primary iron and steel industry, and the changes we can identify within the Canadian economic and policy environments that motivates our empirical investigation.

Collecting the Evidence: The Horses Gather in the Starting Gate

Based on this brief description of the late nineteenth and early twentieth Canadian economic environment, it seems clear that there are a number of horses in the race to explain the industrial development we observe, particularly with respect to the primary iron and steel industry. Literature of both a quantitative and qualitative nature has attributed output expansion, the improved competitive position and the improved
productivity performance of Canadian producers to: falling input prices, the accumulation of experience, increases in international demand, increases in domestic demand, and greater effective tariff and transport protection. More specifically, some have argued that reductions in the marginal cost of pig iron production in Canada were associated with learning-by-doing through cumulative production experience, and decreasing raw material and labour costs stemming from new domestic resource discoveries, internal and international labour mobility, and deskilling technological change (Acemoglu 1998, Goldin and Katz 1998, Adshade and Keay 2010). Others point to the impact that increases in international demand for iron and steel products, particularly during Civil War recovery and rebuilding efforts in the United States, may have had on foreign pig iron prices, and hence domestic import prices. Increases in urbanization, western settlement, infrastructure building, and the wheat boom expansion of population, GNP and GNP per capita have also been identified as important causes of a shift in the domestic demand curve for many industrial products, including the intermediate goods produced by iron and steel mills. US trade policy is supposed to have protected "infant industries" and fostered learning-by-doing, but in this the US is not alone. Substantial increases in the bounties offered to the Canadian primary iron and steel industry, and duties that were imposed on imported substitutes in 1879 and 1887 have long attracted the attention of Canadian scholars because of the claims and counter-claims that have been made about their ability to enhance domestic performance (Harris and Lewis 1992, Naknoi 2010). Finally, coincident with these changes in tariff protection were persistent reductions in rail freight rates, ocean and Great Lake freight rates, and miscellaneous port, insurance and shipping fees. Part of the ongoing debate over the role of transport costs stems from the fact that these costs affect both the prices of imported pig iron and the cost of imported iron ore and coke, such that it is unlikely that there was any simple, linear relationship between transport protection and primary iron and steel production levels or performance after 1870.

Before running a horse race with which we may try to assess the strength of the interdependent and endogenous connections linking any of these potential determinants of industrial development, a brief review of the available evidence and a description of
the chronological patterns that are apparent within the data will help to clarify and motivate the structural framework and econometric analysis that follows.

Industry Performance

Micro-data on furnace specific output, employment and labour productivity can be derived from the manuscripts of the Geological Survey of Canada's annual mining industry census reports, starting in 1887. For earlier years scattered reports in newspapers, magazines, books, archival letters, and various government and non-governmental studies can be compiled to produce a fairly complete, annual series for these performance variables covering 13 blast furnaces (Bartlett 1884, Bell, Geological Survey of Canada, Hardy 1995, Harrington 1974, MacDonald 1909). These furnaces produced just slightly less than 75% of the total pig iron production in Canada, on average between 1870-1913.

In Table 1 we report the sum of the total net tonnage of pig iron produced by these 13 Canadian blast furnaces in 1890, as well as the average annual percentage changes in pig iron production relative to gross national product (GNP) – expressed in constant 1890 Canadian dollars – over the full 1870-1913 period, and over three sub-periods: 1870-1889, 1890-1900 and 1901-1913. Output, like all of the variables employed in our quantitative exercise, is assessed relative to the size of the aggregate economy in an effort to control for aggregate scale effects and to allow us to focus on industry specific, rather than macro-economic relationships. We can see that pig iron output expanded rapidly over the entire period, with relative growth accelerating across each sub-period. In Figure 1a we depict total net tonnage in each year, along with the stationary components of the data series, derived using a Hodrick-Prescott filter. The filtered series helps us to identify long-run, stationary trends, and episodes in which production deviates from these trends.

The dramatic increases in production after 1901 clearly dominate Figure 1a, making any earlier output movements difficult to observe. However, if we consider a truncated version of the full production series, we can identify more subtle changes in

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output levels during the earlier years. In Figure 1b we depict total net tonnage of Canadian pig iron from 1870-1900. In this figure we can see that output was falling during the early 1870s, rising slowly through the late 1870s and early 1880s, then it appears that the early stages of the rapid acceleration that we see after 1900 may have been underway as early as 1890. Tests for structural breaks in the series linear trend confirm the presence of discontinuities in 1890 and 1900.

The employment figures reported in Table 1 represent the number of person days in blast for primary iron and steel producers, relative to total employment in other manufacturing industries (total manufacturing less iron and steel). We can see a similar, although more volatile pattern in employment to that which we observed for output – decline during the early period, followed by rapid increases in employment during the early 1880s and slower, but persistent increases through the 1890s and 1900s.

Domestic producers' market share (Figure 2) was falling sharply during the early 1870s, and despite a discontinuous jump at the expense of US imports in 1876, it was fairly stable through the rest of the 1870s and 1880s. In contrast, the 1890s saw a persistent increase in the Canadian mills' market share – from just under 35% in 1890 to very nearly 90% in 1900. Having captured virtually the entire Canadian market, domestic producers maintained their dominant position until the start of World War I.

The other performance measure we have access to, labour productivity, experienced quite healthy growth during the 1870-1889 period and the post-1900 period, but output per person-day stagnated during the 1890s as the new blast furnaces expanded their workforces at almost that same rate that output expanded.

In Figure 3 we show the net changes in the number of Canadian blast furnaces in operation in each year between 1870-1913. The entry and exit activity captured by this figure appears particularly active during the years surrounding 1880 and during the second half of the 1890s – coinciding closely with increases in production and employment. Between 1879-1884 five furnaces shut down and three more began production, while the 1896-1904 period saw one furnace shut down and six more begin production. These episodes of turn-over represent a regional and technological reorganization of the industry, from charcoal burning mills in Quebec towards much
larger, coke burning mills in Nova Scotia and Ontario.\textsuperscript{3} We suggest that the eventual effects of this reorganization can be seen in the changes in market share and labour productivity reported in Table 1 and Figures 2 and 3.

In general, these summary statistics and figures depict a development pattern that is consistent with that which has been described in the literature on aggregate Canadian industrial performance. The primary iron and steel industry experienced slow decline through the 1870s, the beginning of a turn-around during the 1880s, accelerating growth after 1890, and finally explosive expansion after 1900.

**Supply Conditions**

In the simplest possible terms, the expansion and technological development of the Canadian primary iron and steel industry that began in the 1880s was the result of new investments and industry turn-over that favoured larger, modern, more technologically advanced mills. This observation is not particularly enlightening, unless we can determine why these new investments occurred when and where they did.

The cost of investment funds offers us no help in answering this question. Blast furnaces were certainly capital intensive undertakings that required some combination of deep pockets, a willingness to take on considerable risk, access to foreign capital supplies and/or sophisticated financial intermediation. However, much of this investment may have been funded from retained earnings and local, informal capital markets, and the cost of capital from more formal sources was remarkably stable throughout this period (Keay and Redish 2004, Kilbourn 1960).\textsuperscript{4} These considerations imply that we should not seek to explain any sudden burst of new investment with stable capital prices drawn from a largely unused segment of the capital market. There must have been other changes in supply conditions, such as learning-by-doing or falling raw material and labour costs, and/or demand conditions, such as expanding international or domestic demand and increasing trade protection, that motivated this new investment.

\textsuperscript{3} Between 1870-1890 40% of Canadian output originated in Quebec blast furnaces. Ontario produced no pig iron during these years. Between 1900-1913 Quebec's share of production fell to less than 1% and Ontario's share rose to just over 26% (20% from the Hamilton blast furnaces alone).

\textsuperscript{4} The only formal capital cost figures available for this period are long term government bond yields, which vary between a high of 5% in 1870 and a low of 2.8% in 1897, and have no statistically significant structural breaks in their linear trend between 1870-1913. The simple, unconditional correlation between nominal long term bond yields and pig iron production during this era is -0.211.
In a widely cited article Kenneth Arrow (1962) argued that as firms accumulate production experience workers become more proficient at their assigned tasks, the organizational structure of the firm improves, and micro-adaptations to the technologies employed all combine to improve efficiency, thereby making the firm more competitive. This learning-by-doing among individual firms has been adopted as a theoretically robust justification for the protection of infant industries from foreign competition, and there has been a considerable research effort directed towards the search for an empirical identification of these effects (Fogel and Engerman 1969, Harris and Lewis 1992, Irwin 2000, Irwin and Klenow 1994, Naknoi 2010). Here we have little to contribute to this search because we have no production information for furnaces in operation prior to 1870, and even for those furnaces that entered the Canadian industry during our period of study, output only begins to accumulate in a meaningful way during the dramatic post-1900 output expansion. We have no statistical evidence that our measures of cumulative output have any significant connection to firms' entry decisions or production decisions between 1870-1913.5

Raw material costs, on the other hand, appear to have more potential as an important determinant of new investment and production among Canadian primary iron and steel mills. It takes approximately one and three-quarter tons of iron ore and one and one-quarter tons of coke to produce one ton of pig iron. These two inputs alone account for approximately two-thirds of the value of a ton of pig iron during our period of study. Donald (1915) has argued that the “discovery” of iron ore in northern Ontario and Newfoundland provides a convincing explanation for nineteenth century pig iron output growth.

Donald's new discovery explanation may fit nicely with the traditional "resource dependent" view of Canadian industrial development (Keay 2007, Watkins 1963), but after some careful consideration it is not nearly as compelling as it initially seems. One of the discoveries identified by Donald was not a discovery at all – the ore deposit in Newfoundland was well known and had been tentatively exploited on several occasions.

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5 There is fairly strong evidence that cumulative output and our domestic demand measures are collinear in our empirical exercise, but the demand variables have greater explanatory power so they are retained as independent variables. The simple, unconditional correlation between cumulative output and gross investment is 0.989.
between the seventeenth century and the late 1880s (Inwood 1983, 1986). Although Donald's second iron ore deposit, in northern Ontario, was genuinely "discovered" in 1898 as an unanticipated by-product of a gold rush, none of the Ontario blast furnaces ever actually used this source of raw material (Inwood 1987). Of course, even if there was no dramatic, discovery driven supply curve shift for iron ore, the importance of raw materials in production implies that ore and coke prices still may have played a role in the industry's investment and output decisions.

The raw material prices reported in Table 1 are a weighted average of US iron ore prices (plus the cost to transport the ore from the mine-head in Marquette MI to Hamilton ON) and US coke prices (plus tariffs and the cost to transport the coke from the kilns in Connelsville PA to Hamilton ON), deflated by a Canadian wholesale price index (WPI). The inputs are weighted by blast furnace production elasticities, derived from input intensities reported in the 1880-1910 United States Census of Manufactures. We can see that Canadian raw material prices fell slowly over the entire period, with a notably more rapid rate of decline during the period of the industry's fastest output expansion after 1900.

In addition to raw material costs, labour accounted for the other significant variable input expense for primary iron and steel producers. We do not have access to any information on hourly, daily or weekly wages for Canadian blast furnaces before World War 1. We do, however, have information on aggregate wages and salaries paid in the primary iron and steel industry. We use this information with our employment series for the 13 Canadian blast furnaces in our sample to derive an index of average earnings per person-day, deflated by the WPI. The average annual rates of change for labour remuneration reported in Table 1, and the labour cost series depicted in Figure 4 (along with the stationary component of this series, derived using a Hodrick-Prescott filter) reveal considerable volatility and slowly rising pay through the 1870s and 1880s, followed by more stable, but falling wages throughout the post-1890 period.

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6 Canadian furnaces did finally begin to intensively exploit the Newfoundland deposit during the 1890s, but this development follows a pattern that is much more consistent with an endogenous response to developments within the pig iron markets, rather than an exogenous discovery.

7 By this calculation, the average Canadian primary iron and steel worker earned approximately $0.60 per day in 1890. This is just over half what a US primary iron and steel worker earned at this time (assuming a 10 hour work-day), and it implies just slightly more than 245 work-days per year to reach the average Canadian income per capita level in 1890.
One feature that is particularly note-worthy from Figure 4 is the very sharp drop in remuneration during the early 1880s, which is coincident with the flurry of turn-over activity among the furnaces that we identified in Figure 3. This reduction in real wages is the result of a reduction in aggregate wages and salaries paid in primary iron and steel (Urquhart 1993) and a simultaneous rapid increase in the number of person-days in blast. This decrease in remuneration could potentially be attributed to an increase in the supply of urban workers as a result of increases in rural-urban migration and immigration – urbanization and net migration rates were high during the early 1880s. However, the precipitous nature of the decline in pay during the early 1890s suggests that labour supply responses, which we typically assume to be much more gradual and muted, are unlikely to be the cause. This in turn implies that there may have been something about the new furnaces that were beginning production at this time that drove this reduction in average wages per day – deskillling technological change, perhaps. Unfortunately, a detailed investigation of the source of the wage movements we observe in Figure 4 is beyond the scope of this study. We simply seek to characterize the (conditional) connections that may have linked labour cost movements to the expansion of pig iron production in Canada.

International Demand

The development of the US and British primary iron and steel industries through the nineteenth century has been exhaustively studied by social, economic and technological historians. Although it does not serve our purposes to delve deeply into this literature, we do need to concern ourselves with changes in these foreign markets that may have affected Canadian producers. Specifically, changes in international demand may have had an impact on import prices and hence, the pace and pattern of domestic industrial development. Average US and British pig iron prices (in 1890 Canadian dollars) and average annual rates of change (deflated by a Canadian wholesale price index) are reported in Table 1. We can see that in 1890 US prices were well above those charged by their UK counterparts, but this competitive advantage for British producers would not last. Broadly speaking, the price movements in both nations were similar over the 1870-1913 period – both US and British prices fell during the 1870s, 1880s and after
1900, and both nations’ prices rose during the 1890s. However, British rates of decline during the earliest sub-period were very modest, and the subsequent increase during the 1890s was sharp. US prices, in contrast, fell on average over the entire period, the rates of decline during the first and last sub-periods were steeper, and even the price increases of the 1890s were relatively small. These foreign price movements help to explain why British producers were losing domestic market share to both Canadian and US mills during the years after 1890.

**Domestic Demand**

It is not entirely clear how to best capture domestic demand forces affecting primary iron and steel production. Typically we would simply use aggregate income, income per capita, or population to measure changes in the size and purchasing power of the Canadian market. Davis and Irwin (2007) have argued that for the US at least, these macro-economic indicators are not accurate representations of the source of demand for iron and steel products, but rather a more targeted measure is required. During the late nineteenth century, iron and steel products were used to produce machinery, transportation equipment, building materials, and all forms of infrastructure and investment goods. Davis and Irwin use manufacturing output as a proxy for domestic demand for US pig iron. Given the demographic events that were occurring in Canada between 1870 and 1913, we might also want to consider using some measure of urbanization, western settlement, railway building, or simply net migration. Of course, all of these measures capture some contributing factor, or a particular segment of aggregate gross investment in Canada.

In Table 1 we report average annual rates of change for real income per capita, the share of manufacturing value added in GNP, the urban share of the population, and the share of gross investment in GNP. We can see that for all these measures, aside from manufacturing, which grows at virtually the same rate as GNP throughout, the chronological patterns are similar. Domestic demand determinants appear to have grown modestly during the 1870s and 1880s, slowing during the last half of the 1880s and into the 1890s, before accelerating rapidly after the mid-1890s. In Figure 5 we depict the broadest measure of these domestic demand determinants that we have access to - the
share of gross investment in GNP (and the stationary components of this series). We can clearly see the slow rise – stagnation – sharp rise pattern in this figure. It is interesting to note that the beginnings of expansion in iron and steel, and the technological and geographic transformation of the industry appear to coincide with the period of slow growth and/or decline in the domestic demand indicators, but the subsequent post-1900 macro-economic expansion very closely chronologically matches the take-off in domestic pig iron production.

Tariff Protection

Some Canadian scholars have argued that the National Policy tariffs that were imposed in 1879 may have reduced income per capita and population, contributed to a slowdown in aggregate productivity growth, and interrupted the spatial process of industrial centralization (Dales 1966 and 1979, Inwood 1991). However, aggregate data reveal little evidence of any of these effects. Between 1870-1913 the manufacturing share of gross domestic product fluctuated from 21-25%, with no trend attributable to rising tariffs, and the manufacturing sector’s share of all capital formation remained stubbornly low throughout the decades immediately following 1879. Domestic prices may have been insensitive to the tariff because many commodities were exported, or because import competition was suppressed by transportation costs, perishability and/or market specific services delivered with the commodity (Drummond 1987). Even a tariff that succeeded in raising prices may not have influenced production if input supplies were inelastic, if the tariff on inputs increased at the same time, or if the industry was already sufficiently profitable in the absence of trade protection.

However, if tariffs were important for any industry in Canada, the primary iron and steel industry would be a likely candidate. When the National Policy was introduced, iron importers and consumers successfully held the iron tariff to the relatively low level of $2 per ton (Canada 1881 and 1882, Forster 1986). The iron lobby gradually gained ground in successive revisions of the National Policy. Particularly important was a doubling of the iron tariff in 1887 to $4 per ton by the new Finance Minister Charles Tupper. The effect of these changes can be seen in the summary statistics reported in Table 1 and the series depicted in Figure 6. Until 1879 there was no tariff protection for
domestic pig iron, but over the next 11 years a combination of falling duties on US coke, rising bounties paid per net ton produced in domestic blast furnaces, and rising tariff rates on US and UK imports combined to raise the ad valorem rate of effective tariff protection to 18%. This rate peaked at just less than 30% in 1893, before falling slowly through the rest of our period of study. Federal elections repeatedly fought over the issue of trade policy (in 1878, 1887, 1896 and 1911), pitted protectionist Conservatives against free trade Liberals. The outcomes from these elections are clearly discernable in the ad valorem rates - Conservative wins in 1879 and 1887, and Liberal wins in 1896 and 1911. Of course, tariffs and bounties only tell part of the story when it comes to protection from foreign competition.

Transport Protection

Inland iron producers in Canada and the United States experienced an enormous reduction in gross transport protection during the course of the nineteenth century. It has been estimated that the cost of shipping pig iron from Britain to Lake Ontario declined from approximately 6.5 pounds sterling per ton during the 1820s, to just over 1 pound sterling at the end of century (Inwood 1992). This implies an average rate of decline in excess of 20% per decade. Of course, reductions freight rates also influenced the cost of imported raw materials for Canadian mills, such that the net effect of transport improvements were never unambiguous or immediately obvious.

In Table 1 we report transport costs per net ton of pig iron for water and/or rail routes from: Liverpool UK to Hamilton ON; Pittsburgh PA to Hamilton; the Marquette MI iron ore mines to Hamilton; and the Connelsville PA coke kilns to Hamilton. These summary statistics reflect the collection of a new series of west-bound ocean freight rates from Liverpool-Montreal, based on British Board of Trade Reports, and a more complete accounting of all shipping fees and charges on all four of these routes. In past studies of the international trade in pig iron, transport costs have either been ignored (Davis and Irwin 2007), or estimated on the basis of east-bound freight rates for grain (Naknoi 2010). Given that the prevailing winds and ocean currents favour east-bound trans-Atlantic voyages, and technological improvements were consistently directed towards reducing shippers’ reliance on these inherently unreliable winds and currents (Harley 1988 and
1889), it is not surprising to see in Figure 7 that there was a significant difference in favour of east-bound versus west-bound freight rates, but this difference was declining over the 1870-1913 period. From Table 1 we can see that transport costs were declining on all routes over almost all sub-periods, but the intra-continental shipping costs for ore and coke were falling the fastest.

The cost to ship inputs to a blast furnace in Hamilton declined from $17.25 CAD in 1870 to just over $5.50 in 1913. These intra-continental transport savings were achieved through technological improvements in rail, Great Lakes steamers, and fuel efficiency (Allen 1977, Fishlow 1966, Laurent 1983, Williamson 1977). About two thirds of the savings were made in the over-land transportation of coke, while the remaining one-third reflects a dramatic fall in the cost of ore carriage on the Great Lakes.

During the 1870-1913 period the cost to ship pig iron from Liverpool to Hamilton declined from $11.75 to $5.75, and the cost to ship pig iron from Pittsburgh to Hamilton dropped from $3.50 to just under $1.50. As these figures imply, falling transport costs caused the price of British imports to fall by $6 ($2 for US imports), while per unit input costs in Canada fell by $11.75. The net impact of transportation improvements, therefore, increased effective protection for a blast furnace in Hamilton by at least $5.75 – roughly the same magnitude as the change in the value of the effective tariff between 1870 and its peak in 1894-1895.

In Figure 6 we illustrate the combined effect of the changes in Canadian primary iron and steel producers’ effective ad valorem tariff protection and effective ad valorem transport protection between 1870-1913. Effective transport protection was consistently negative throughout this period, but the relative improvement in input shipping costs was reducing the size of this disadvantage, such that by 1884 the effect of increased tariffs and bounties, the removal of the duty on imported coke, and the reduction in North American rail and Great Lakes transport costs resulted in cumulative effective protection becoming positive for domestic producers for the first time. This positive effective protection was not substantial – only approaching 10% during the late 1880s, mid-1890s, and mid-1900s – but it was persistent, and it survived cuts in the tariff rates that followed Sir Wilfred Laurier’s Liberal election victory in 1896.
Providing Some Structure for the Problem

Visual inspection of the average annual rates of change reported in Table 1, and the chronological patterns that can be identified in Figures 1a-7 can suggest to us where unconditional correlations may link pig iron production to supply and demand conditions, and policy objectives. However, these potential performance determinants are neither obviously exogenous, nor independent. To evaluate the strength of the conditional correlations that exist among these interdependent variables, we must introduce some statistical rigor into the horse race we wish to run among the potential explanations for the development of the Canadian pig iron industry between 1870-1913. The need for statistical rigor, in turn, requires that we first impose some structure on the problem we face.

Our objective in this study is to establish why new Canadian blast furnaces began production, and once they chose to enter, what determined how much they produced? Based on our review of the international and Canadian literature on late nineteenth and early twentieth century industrial development, and the evidence that is available to us, we have isolated labour costs, raw material costs, international demand, domestic demand, and effective tariff and transport protection as the most reasonable candidates for further investigation in our search for a response to these two basic development questions. Ultimately, therefore, all we wish to know is how sensitive domestic producers were to each of these six features of the iron and steel mills’ economic environment. We could adopt a fully dynamic, structural approach to the estimation of the sensitivity of pig iron producers' entry and output decisions, but our data (13 furnaces over just 44 years) is unlikely to support this exercise, and it would accomplish very little beyond what a simpler, reduced form, partial equilibrium model can provide.

Davis and Irwin's (2007) investigation into the role US tariffs played in fostering the early development of the US pig iron industry sought to achieve many of the same goals we have established here. With some adaptations, we employ a reduced form demand and supply model very similar to that used by Davis and Irwin to structure and motivate our econometric exercise. This model is based on a theoretical exposition developed by Grossman (1986), in which domestic production and foreign imports are
assumed to be imperfect substitutes, and the endogeneity of domestic prices and output levels can be resolved at the outset by assuming that equilibrium is achieved in the domestic market in each discrete time period. More formally, domestic supply is assumed to be a function of domestic input \((W_M \text{ and } W_L)\) and output \((P_{Cda})\) prices, while domestic demand is assumed to be a function of domestic output prices \((P_{Cda})\), import prices \((P_{For})\), tariff \((\tau)\) and transport protection \((T)\), and demand determinants capable of shifting the entire price-quantity schedule \((DomD)\).

\[
\ln(Q_s) = \alpha_0 + \alpha_1 \ln(P_{Cda}) + \alpha_2 \ln(W_M) + \alpha_3 \ln(W_L) + \varepsilon \\
\ln(Q_d) = \beta_0 + \beta_1 \ln(P_{Cda}) + \beta_2 \ln(P_{For}) + \beta_3 \ln(\tau + T) + \beta_4 \ln(DomD) + \varepsilon
\]

We can derive a single, reduced form expression which captures all the determinants of domestic supply decisions and explicitly accounts for the endogeneity of domestic prices, by solving for domestic prices in the demand equation (1), substituting into the supply equation (2), and isolating output on the left-hand-side (while maintaining the assumption that \(Q_d = Q_s\) at each point in time).

\[
\ln(Q) = \eta_0 + \eta_1 \ln(P_{For}) + \eta_2 \ln(\tau + T) + \eta_3 \ln(DomD) + \eta_4 \ln(W_M) + \eta_5 \ln(W_L) + \varepsilon
\]

Each of the parameters \((\eta_0 - \eta_5)\) in this expression represent aggregate elasticities. \(\eta_2\) for example, captures the percentage change in output that results from a 1% change in tariff and transport protection \((\eta_2 = -\frac{\alpha_1 \beta_3}{(\beta_1 - \alpha_1)})\). The net response to changing protection levels depends on the elasticity of domestic supply \((\alpha_1)\), the domestic price elasticity of demand \((\beta_1)\) and the protection-induced elasticity of demand \((\beta_3)\). This aggregate elasticity will be positive if supply curves are upward sloping \((\alpha_1>0)\), demand curves are downward sloping \((\beta_1<0)\) and domestic and foreign output products are substitutes \((\beta_3>0)\). A more structural approach would allow us to estimate each of these demand and supply elasticities separately, but because we are only interested in the producers’ aggregate responses to movements in each of the explanatory variables, identifying the decomposed elasticity parameters is not necessary. This final expression

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8 Tariffs and transport costs are measured per net ton of pig iron. Because transport costs have an impact on import prices and raw material prices, their measured effect in the demand equation will represent their net impact on production and entry decisions.

9 Time and furnace subscripts are suppressed. Error terms are assumed to be white noise.
– Equation (3) – forms for the basis for the first of our econometric exercises, which seeks to estimate the sensitivity of Canadian pig iron supplies to international demand, effective tariff and transport protection, domestic demand, raw material prices and labour costs.

**Estimating Supply Responses**

We make only one change to the definitions that have already been provided for the variables included in Equation (3) before taking this model to the data. To isolate industry specific responses and to control for aggregate scale effects associated with macro-economic movements, all dependent and independent variables used in our econometric exercise have been measured relative to their economy-wide, aggregate counterparts. For example, consistent with the evidence presented in Table 1 and Figures 1a-7, Canadian pig iron output has been measured relative to real GNP, foreign prices, protection, raw material costs, and labour costs have all been measured relative to a wholesale price index, and domestic demand has been measured relative to nominal GNP. Pig iron output has been aggregated up from furnace specific figures, so it includes only the production from the 13 furnaces in our sample. Our benchmark specification uses a weighted average of US and British pig iron prices, with total imports as weights, as a measure of foreign prices. A weighted average of the tariffs imposed on US and British imports, again using total imports as weights, has been used to measure tariff protection, while the same weights are applied to Pittsburgh-Hamilton and Liverpool-Hamilton pig iron transport costs to measure transport protection.\(^{10}\) Aggregate raw material prices have been calculated as a weighted average of coke and iron ore prices, using US production intensities as weights. Finally, gross investment has been used to measure domestic demand because it casts the widest net in an effort to capture all of the sources of demand for primary iron and steel products, including expenditures on private

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\(^{10}\) US and British exporters faced identical Canadian tariffs until 1907, when British producers received a small preferential reduction.
industrial capital, transportation, public and urban infrastructure, and public and private buildings.\textsuperscript{11}

**Aggregate Production**

Armed with our reduced form estimating equation we begin with a benchmark specification that assesses the aggregate primary iron and steel industry’s output responses to changes in international demand ($P_{for}$), protection ($\tau + T$), domestic demand ($Dom_D$), raw material prices ($W_M$), and labour costs ($W_L$). In this first specification we assume that producers did not distinguish between US and British imported pig iron prices, coke and ore raw material prices, or protection derived from transport costs and tariffs, we measure all variables at their static levels in each year between 1870-1913, and we simply run our regression using ordinary least squares. In the first column in Table 2 (Levels – OLS – Model I) we report the parameter estimates from this first specification, along with the relevant p-values, derived using Huber-White robust standard errors. We can see that, as we expect, protection and domestic demand are strongly positively related to industry output, and raw material and labour costs are strongly negatively related to industry output, but the connection between foreign prices and Canadian pig iron production is surprisingly weak and statistically indistinguishable from zero. We may interpret each of these parameter estimates as aggregate elasticities. Therefore, the estimate we report for protection, for example, indicates that on average a 1% increase in tariffs and transport costs per net ton of pig iron was associated with a 0.9% increase in domestic output, holding all else constant. Similarly, a 1% increase in the weighted average of raw material prices was associated with a 1.2% reduction in output.

In this first specification we treat all imports, raw materials and sources of protection as perfect substitutes in the Canadian market. Including US and British import prices, and coke and iron ore import prices separately in our regression equations allows us to estimate different production elasticities for each product and input. In addition, producers may have viewed tariff and transport protection as imperfect substitutes

\textsuperscript{11} Using manufacturing output, western settlement, net migration, or railway building as a proxy for investment demand has no appreciable impact on any of our qualitative conclusions.
because, for example, transport costs affect import and input prices simultaneously.\textsuperscript{12} On the other hand, there may also have been less certainty regarding the permanence of tariff protection because, perhaps, election results and the vagaries of government support may have been unpredictable. As a result of these considerations, we introduce a second specification, in which we relax our assumption that there were common responses to American and British imports, both raw material inputs, and tariff and transport protection. In the second column of Table 2 (\textit{Levels – OLS – Model 2}) we report the parameter estimates (and p-values) from the estimation of this second specification. We can see that US and UK imports, and coke and iron ore costs have different effects on Canadian pig iron production.\textsuperscript{13} Domestic demand and labour costs still have the expected signs and they remain statistically significant. However, transport costs are negatively correlated with output (and significant), indicating that input cost considerations may have dominated producers’ sensitivity to rail and water freight rates, while tariffs remain strongly positively correlated to domestic production. In both specifications we can see important connections linking the performance of the primary iron and steel industry to labour costs, domestic demand forces, and policy induced trade protection.

Unfortunately, there are a number of potential problems with the results reported in the first two columns in Table 2: the OLS estimates suffer from serial correlation among the regression residuals; the presence of non-stationary explanatory variables introduces the possibility of spurious regression results; and concerns about endogeneity bias associated with tariff protection, domestic demand, and labour costs may lead to inconsistent estimates. We deal with the endogeneity problem by adopting an instrumental variables (IV) approach and re-estimating Model 1 and Model 2.

Our concern with the parameter estimates associated with tariff protection, domestic demand and labour costs in Models 1 and 2, is that the direction of causation implied by the structure of Equation (3) may be incorrect. Increases in gross investment, for example, may very well generate demand for primary iron and steel products and

\textsuperscript{12} Tariff and transport costs are captured in our measure of raw material prices, but they are "buried" in the prices, so cannot be included independently from our protection measure. The tariff on coke was set at $0.50 per ton between 1879-1893. There were never tariffs imposed on ore imports.

\textsuperscript{13} The negative conditional correlation between British import prices and Canadian production is consistent with the presence of some degree of complementarity between Canadian and British products.
induce an increase in output, but an increase in the supply of iron and steel products may also reduce the cost of investment goods and induce a subsequent increase in investment. It is not clear which of these variables is necessarily the dependent variable, and this endogeneity introduces the possibility that there may be bias in the parameter estimates and the reported standard errors may be inaccurate. For labour costs, our benchmark results imply that lower wages shift firms' marginal costs downwards and induce an increase in output, but increases in output may just as easily increase the demand for labour and affect subsequent wage rates. Our treatment of tariffs introduces a similar problem, except in this case we must concern ourselves with the political economy of trade policy. If one of the objectives of trade policy is to induce industrial development among primary iron and steel producers, then evidence of this development taking hold may trigger further adjustments to trade policy, either because tariffs have been successful in accomplishing the government's initial objective, so it is politically valuable to raise them further, or because they are seen to have accomplished their goal, so they are no longer necessary. In all of these cases, to remove the potential bias and correct the standard errors in our initial parameter estimates, we must find instruments that are correlated with our endogenous independent variables, but uncorrelated with our dependent variable (except through their role as an instrument).

In the first stage of our IV estimation approach, we use US and UK domestic saving rates as instruments for gross investment ($Dom_D$). Because much of the capital available to late nineteenth and early twentieth century Canadian financial markets was provided by foreign investors, these instruments capture domestic investment supply forces that are plausibly exogenous with respect to pig iron output, except through their impact on gross investment. We also use US and UK real unskilled wage rates, US immigration rates and British emigration rates as instruments for labour costs in our first stage regressions. As a result of the high degree of internal and external labour mobility in the Canadian market, we believe that these instruments can capture labour supply determinants and the opportunity cost of supplying labour to domestic iron and steel mills.

14 The $F$ Statistics from the first stage regressions are: 13.58 for gross investment, 23.21 for labour costs, 17.67 for aggregate protection. With standard levels of statistical significance, Hausman specification tests and Sargan over-identification tests confirm our concerns about the presence of endogeneity and the exogeneity of our instruments, respectively. Complete econometric results are available from the authors.
– all of which may plausibly affect the wages paid to blast furnace workers, without directly affecting production decisions. Finally, for tariff protection we use US pig iron duties and US pig iron production levels as plausibly exogenous instruments. These instruments are meant to capture determinants of the vigour of political support for the imposition and maintenance of Canadian pig iron duties that are independent of the rate of expansion of domestic production.

In the third and fourth columns in Table 2 we report the parameter estimates (and p-values, derived from multi-stage generalized least squares) from the second stage of our IV approach, using the instrumented independent variables from the first stage regressions. Although the standard errors are affected, and the size of some of the parameter estimates changes, in general the conclusions we can draw from these IV results are consistent with those we reached on the basis of our OLS results. In particular, protection, tariffs and domestic demand are strongly positively related to pig iron production, while labour costs are strongly negatively related to output. Transport costs, foreign prices and raw material costs continue to have a weak and variable relationship with output.

The IV estimates indicate that between 1870-1913 a 1% increase in effective protection \((\tau + T)\) was associated with a 1.02% increase in pig iron production (slightly higher than the OLS estimate), while a 1% increase in tariff protection alone \((\tau)\) was associated with a 0.64% increase in pig iron production (again, slightly higher than the OLS estimate). After instrumenting, we can see that 1% increase in domestic demand was associated with a 1.6% \((\text{Levels} – \text{IV:GLS – Model 1})\) to 2.1% \((\text{Levels} – \text{IV:GLS – Model 2})\) increase in pig iron production, while a 1% increase in labour costs was associated with a 2.1% to 1.3% reduction in pig iron production. These IV elasticities for \(D_{omD}\) are slightly lower than the OLS estimates, and the \(W_{L}\) elasticities are slightly higher than the OLS estimates. Of course, even though the parameter estimates reported in columns 3 and 4 of Table 2 do control for endogeneity bias, they do not take into account time series concerns with the data.

Phillips-Perron unit root tests confirm that over the full time period (although not the sub-periods identified in Table 1) many of the series employed in these specifications are non-stationary in levels, but stationary in first differences. To control for the possible
estimation of spurious correlations and problems associated with serial correlation among
the regression residuals, we run Model 1 and Model 2 on first differenced data. We can
see from the estimated parameters (and p-values) reported in Table 2 under the column
headings First Differences - OLS - Model 1 and Model 2, and First Differences - IV:GLS
- Model 1 and Model 2, that statistical power is lost when we move to first differences.\textsuperscript{15}

The key results from the first differenced OLS regressions include the continued
negative impact of labour costs, the now strongly positive connection between increasing
foreign prices and expanding pig iron production, and the reduction in statistical
confidence with which we may conclude that increasing protection and increasing
domestic demand were associated with increasing production. When we consider the IV
estimates we see that the strong protection-production connection re-established
(particularly for tariffs alone), the negative correlation between labour costs and output
also remains, but after instrumenting increasing domestic demand still appears only
weakly linked to rising production.

If we step back and consider all of the results from the eight econometric
specifications reported in Table 2, it appears that protection and tariffs are quite
consistently positively correlated with increases in pig iron production, domestic demand
is also positively correlated with output expansion, although the statistical confidence
with which we may make this claim is more variable, and with no exceptions, labour
costs are negatively correlated to output expansion. The connections between aggregate
pig iron production and foreign prices, raw material costs and transport protection are
much weaker and inconsistent across models and estimation approaches.

We can use the aggregate production data and our reduced form estimating
equations to conduct an additional investigation probing the chronological patterns we
observe in the summary statistics and data series reported in Table 1 and Figures 1a-7. If
we repeat our OLS and IV estimation procedures, but introduce a linear spline with knots
at 1890 and 1900 – interacted with the protection, domestic demand and labour cost
independent variables – we find that the connections between these determinants and

\textsuperscript{15} This loss in statistical power also affects the IV diagnostic tests - the Sargan tests still confirm the
exogeneity of the instruments, but the F-tests suggest that the instruments are weak in their first differences,
and we cannot confirm the endogeneity of changes in tariff protection, domestic investment and labour
costs with any standard level of significance.
output vary widely over three sub-periods: 1870-1889, 1890-1899 and 1900-1913. During the early period, as the regional and technological re-organization of the industry is taking hold, protection and tariffs are very strongly positively related to production in all specifications, but the labour cost and domestic demand elasticities are insignificant. Between 1890-1899, as the new Ontario mills began to enter, labour costs dominate, protection is less important, and domestic demand remains only weakly correlated to production. Finally, during the post-1900 period, all specifications reveal domestic demand elasticities that have become strongly significant, while labour costs still matter, but protection now has very low elasticities that are statistically indistinguishable from zero. Parameter stability tests using a rolling regression (with a 20 year window) confirm that the protection, domestic demand and labour cost elasticity estimates do not maintain their sign or significance consistently over the full 1870-1913 period. There appear to be different forces driving pig iron production decisions at different points in time – protection matters early, labour costs matter during the 1890s, and domestic demand (and to a lesser extent labour costs) matter during the first decade of the twentieth century. These findings are consistent with not only our visual inspection of the series depicted in Figures 1a-7, but some of the infant industry literature that argues in favour of a consequential National Policy impact. In light of these differential sub-period effects, it seems reasonable to seek some more robust statistical evidence that may help us to understand the strength and nature of these complex and fluid aggregate output elasticities. If we only had access to 44 years of aggregate data (and hence, very limited degrees of freedom), it would be difficult to conduct a more detailed investigation of the nature of the Canadian iron and steel mills' joint entry and production decisions during the key 1870-1913 development phase.

Blast Furnaces' Entry and Production Decisions

Our aggregate production information may be chronologically limited, but the industry totals have been derived from a sample of 13 Canadian blast furnaces. With

16 These furnaces include five from Quebec: St. Maurice (1738-1882), L'Islet (1798-1877), Radnor (1860-1910), St. Francis (1869-1877), Drummondville (1869-1911); three from Nova Scotia: Londonderry (1848-1908), Pictou (1892- ), Sydney (1901- ); and five from Ontario: Hamilton (1896- ), Deseronto (1899- ), Midland (1900- ), Algoma (1904- ), Port Arthur/Port Colbourne (1907- ).
the micro-data from each individual furnace we can construct a panel that dramatically increases our available degrees of freedom (572 observations in total – 232 observations with positive output), which facilitates the adoption of a slightly more sophisticated econometric approach that can help us consider the furnaces' joint entry and production decisions.

Heckman’s (1979) selection model was developed to help labour economists deal with a potential bias in their wage equations that results from workers’ need to make two, joint decisions when agreeing to accept an offered wage. Any workers that appear in a data set with a positive wage must have first decided to enter the job market before accepting employment at a given wage. What this structure in workers’ decision making process implies is that one set of determinants affects the decision to enter the job market, and another (possibly overlapping) set of determinants affects the level of wages they are willing to accept. If the researcher ignores the first part of this process when estimating a wage equation, the results will be biased because only those who first chose to enter are observed. This problem can be overcome with a selection model which uses a two stage maximum likelihood approach – a probit, with a [0,1] dependent variable indicating positive production in the first stage, and a linear wage equation (or production equation) in the second stage.

In Tables 3a and 3b we report the parameter estimates (and p-values) from two specifications of Heckman’s selection model. In both specifications we follow Scarpetta, Hemmings, Tressel and Woo (2002), and Black and Strachan (2002) in constructing a first stage entry equation in which furnaces' decision to produce or not is dependent on the expected profitability of their investment in the fixed costs of entry. Expected profitability of entry depends on not only supply and demand determinants, but the competitive structure of the market and the cost of investment funds.

\[ Entry = \delta_0 + \delta_1 \ln(\text{Competition}_{t-1}) + \delta_2 \ln(\text{Production}) + \delta_3 \ln(W_{K}) + \varepsilon \]  

We use the number of furnaces in operation in the period before the entry decision is being made, the aggregate output (relative to real GNP) of these competitors, and their average age as indicators of the extent of competition any new entrant might face. The supply and demand determinants that affect entry are simply taken from Equation (3), and investment costs are assumed to be reflected in long run Canadian government bond
yields and the size of the investment under consideration, measured as the furnace's market share in period $t+1$. The second stage production equations for both specifications are based on Equation (3), with foreign prices, protection, domestic demand, labour costs and raw material costs as explanatory variables.\footnote{We could include furnace specific cumulative output in our production equations, but this would force us to drop four of our furnaces (because we have no production information before 1870), and our results would not be comparable to our benchmark aggregate production equations. We do include the impact of cumulative output when we perform our counterfactual experiment, described below.
}

Similar to the approach we adopted with our aggregate production equations, the first specification of our selection model – \textit{Model 3} – assumes common responses to foreign imports, regardless of the location of production, all raw material costs, and all sources of protection. The second specification – \textit{Model 4} – relaxes these assumptions by allowing for different responses to US and UK imports, coke and iron ore inputs, and tariff and transport protection. Both the first stage entry equations and the second stage production equations may suffer from endogeneity bias. We make an effort to control for endogeneity by again implementing a multi-stage generalized least squares approach to instrument for tariff protection, domestic demand and labour costs, using the same instruments that we employed in our aggregate production equations.\footnote{Our IV estimates are complicated by the need to correct for cross-panel, cross-time, selection and endogeneity biases in the derivation of our standard errors. We follow Worswick (1996) in using GLS to instrument in our first stage probits, then including the resultant nonselection hazard ratios in second stage GLS instrumenting equations and final stage production equations. Alternate approaches using bootstrapped standard errors do not substantively alter any of our qualitative conclusions.}

For each specification we also report p-values derived using Huber-White robust standard errors, clustered by year, and we include furnace group fixed effects. The furnace groups are identified by the vintage of their technology – charcoal burning furnaces (those in operation at the start of the sample period) and coke burning furnaces (those that began operations after 1879). The clustering correction and the inclusion of fixed effects control for cross-furnace heteroskedasticity and serial correlation among the regression residuals.\footnote{These models have been run with year fixed effects and clustering by furnace without substantively altering the qualitative conclusions.}

From Table 3a we can see that if we assume that firms make their entry decisions based on common responses to imports, raw materials and protection (\textit{Model 3 – Probit and Probit: IV}), then protection appears to have been strongly positively correlated with...
the decision to enter the market, although the marginal impact of protection on the probability of entry drops considerably when we control for potential endogeneity bias. Domestic demand and labour costs also have the expected effect on entry, with or without instrumenting, as does the size of the investment commitment (Market Share_{t+1}) and the size of the competing furnaces (Aggregate Q_{t-1}). The other measures of competition in the market, the demand and supply determinants, and capital costs have weaker and more variable effects on entry.

If we allow for the possibility that firms make their entry decisions based on differential protection, import price, and input price effects (Model 4 – Probit and Probit: IV), then we can see that tariffs still have a positive impact on entry, but again after controlling for endogeneity bias this impact is smaller (although still statistically distinguishable from zero). In the Model 4 specification we can also see that domestic demand and labour costs still have the expected effects, and transport protection has a negative but insignificant impact on entry. This result reinforces our view that the effect of transport costs on input prices weakly dominated the import protection effect.

Turning to the primary focus of our exercise, in Table 3b we report the parameter estimates (and p values) from the second stage production equations. The results are reassuring and we can be brief in our assessment. A 1% increase in aggregate effective protection was associated with a 1.5% increase in furnace production levels, conditional on entry. This effect increases to 1.45% if we use US duties and US pig iron output levels to instrument for Canadian protection. If we consider effective tariff protection alone, a 1% increase was associated with a 0.7% - 0.42% average output boost. All of these elasticities are strongly statistically significant. Although the point estimates are smaller and the standard errors slightly larger (with and without instrumenting), in both specifications domestic demand continues to have a strong positive correlation with output decisions, even after we control for their impact on entry. Labour costs appear to have been consistently negatively correlated with output levels, but again the elasticities are smaller after we control for selection. Raw material costs and foreign competition continue to have relatively weak and variable effects on furnaces' production levels.

As we did with the aggregate production equations, we again use a linear spline with knots at 1890 and 1900 – interacted with protection, domestic demand and labour
costs – to allow for differential effects across three sub-periods: 1870-1889, 1890-1900 and 1901-1913. Just as we found with the aggregate data, the tariff’s impact on entry was strongest during the first sub-period, labour costs’ impact on production was strongest during the second sub-period, and the impact of domestic demand on production was strongest during the third sub-period.

With two simple "back-of-the-envelope" counterfactual exercises we can conclude this investigation by providing some economic context for the results we have reported from our econometric models. Using the production equation's parameter estimates from Model 4 - IV: GLS (included in Table 3b), we can derive annual predicted output levels for each furnace in our sample. We can then calculate the reduction in production that would have resulted from the removal of all effective tariff protection. In other words, in this first experiment we ask what furnaces would have produced if the Federal Government in Canada had not imposed the National Policy tariffs in 1879 or the Tupper Tariffs in 1887.20 The results from this experiment are depicted in Figure 8 (Without Cumulative Q). We can see that after 1879 pig iron production would have dropped substantially. On average over the full 1870-1913 period aggregate production would have been 34% lower, and during the last decade of the nineteenth century Canadian pig iron production would have dropped by more than 51%. Of course, if we accept the infant industry justification for protection, then the year-over-year output reductions implied by this initial counterfactual experiment may also have slowed the accumulation of production experience and learning-by-doing, such that there may have been even more persistent and indirect effects on productivity and production.

In a second counterfactual experiment we re-estimate our Model 4 two-stage Heckman selection model, again instrumenting for potential endogeneity bias among the tariff, domestic demand and labour cost explanatory variables. However, in this second experiment we constrain our sample to include only the nine furnaces that entered during our study period (for which we can calculate cumulative output figures), and we include lagged cumulative output, measured relative to real GNP, as an explanatory variable in the selection and production equations. In this specification of our model, lagged

20 Of course this simple experiment ignores the entry and turn over that was triggered by effective protection. We are, therefore, forcing all furnaces to enter and exit as they would have in the presence of the tariffs.
cumulative output and tariff protection are strongly positively correlated with the furnaces' production decisions, conditional on entry.\footnote{A full set of econometric results from this re-estimation of our selection model on the nine furnace subsample is available from the authors.} We derive furnace specific counterfactual production predictions in the presence of cumulative output effects by iteratively removing the effect of tariff protection in each year, then re-calculating predicted production levels up to period $t-1$ and using these "zero tariff" predictions to derive counterfactual lagged cumulative production levels. The counterfactual cumulative production levels are then used to remove the cumulative output effect in period $t$ and the iterative process is repeated. The results from this second counterfactual experiment (Including Cumulative Q Impact) are depicted in Figure 8. We can see that until the turn of the twentieth century the year-over-year impact of removing Canadian pig iron protection is larger if we ignore the cumulative output effect, but as our experiment moves forward through the sample period the cumulative output effects grow, and these effects persist even after the removal of effective protection. By 1913 the counterfactual aggregate output levels from our second experiment (including cumulative output effects) are more than 10% lower than those derived from our first experiment (without cumulative output effects). When we consider the effect of lost production experience, on average over the full 1870-1913 period Canadian pig iron production would have been 30% lower in the absence of effective tariff protection. Clearly, effective tariff protection had a substantial and potentially persistent positive impact of the size and development of the Canadian primary iron and steel industry.

**Conclusion: The Horses Reach the Wire**

Much has been written about late nineteenth and early twentieth century industrial development, both in Canada and among many of the Atlantic Economies. The efficient production of primary iron and steel products on a large scale has often been used as a proxy for industrial success during this era, and the industry is commonly used as a case study to investigate the impact of market expansion, endogenous technological change, falling transport costs and changing tariff protection on industrial development. In
Canada the primary iron and steel industry was in decline during the 1870s, but a flurry of entry and exit that favoured large, technologically advanced coke burning mills occurred during the 1880s and 1890s. Production expanded, productivity improved and domestic producers’ market shares began to rise. Through the 1890s output growth was steady, but after 1900 production increased dramatically and domestic market share remained at or above 90% until the end of our study period. In 1879 and 1887 the Canadian government sharply increased tariff protection for pig iron. Throughout the 1870-1913 period transport costs were falling, but this favoured the domestic mills’ input costs more than foreign suppliers’ import prices. After 1890 labour costs fell in primary iron and steel, then, starting in the late 1890s, Canada’s wheat boom took hold and “all ships seemed to rise with the tide”.

Based on our reading of the literature on industrial development after 1870, it seems that there are six horses in the race to explain the growth and technological development of the Canadian primary iron and steel industry: increases in international demand, increases in domestic demand, reductions in raw material prices, reductions in labour costs, falling transport costs, and rising effective tariff protection. A reduced form demand-supply model forms the basis for our aggregate industry production equation, which we use to estimate the sensitivity of domestic production to changes in each of these potential determinants. We find that domestic demand, labour costs and tariff protection have the largest and most significant elasticities, but these elasticities were not stable over the 1870-1913 period. Pig iron production seems to have been most sensitive to tariff levels early in our study period, labour costs during the middle years, and domestic demand at the end of our period. The use of furnace level micro-data with a Heckman selection model and two back-of-the-envelope counterfactual exercises provides us with an opportunity to perform more narrowly focused tests of these claims. The evidence appears to be consistent with the view that tariff protection was required to trigger entry and new, irreversible investment in larger, technologically advanced blast furnaces, and only then did falling labour costs and increasing domestic demand encourage output expansion.

The implication that can be drawn from our econometric exercises and concluding counterfactual experiments, therefore, is that some of the horses in the race clearly were
not winners (international demand, raw material costs and transport costs), and although the combination of domestic demand and labour costs do appear to have ultimately won the race, they never would have had a chance to reach the finish line if tariff protection had not started off the race well ahead of the pack.


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Inwood, K.E. (1986b), "Local Control, Resources and the Nova Scotia Steel and Coal Company", Historical Papers, Pg. 254-82.


### Table 1: Performance, Input Prices, Demand and Protection

<table>
<thead>
<tr>
<th></th>
<th>Levels: 1890</th>
<th>1870-1913</th>
<th>1870-1889</th>
<th>1890-1900</th>
<th>1901-1913</th>
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</thead>
<tbody>
<tr>
<td>Q/Real GNP</td>
<td>38432</td>
<td>0.080</td>
<td>0.043</td>
<td>0.087</td>
<td>0.126</td>
</tr>
<tr>
<td>L/Manu L</td>
<td>29563</td>
<td>0.027</td>
<td>-0.042</td>
<td>0.080</td>
<td>0.084</td>
</tr>
<tr>
<td>Market Share</td>
<td>0.342</td>
<td>0.005</td>
<td>-0.028</td>
<td>0.046</td>
<td>0.017</td>
</tr>
<tr>
<td>Q/L</td>
<td>0.737</td>
<td>0.071</td>
<td>0.082</td>
<td>0.026</td>
<td>0.092</td>
</tr>
<tr>
<td>Real WL</td>
<td>$0.59</td>
<td>-0.007</td>
<td>0.046</td>
<td>-0.067</td>
<td>-0.035</td>
</tr>
<tr>
<td>Real WM</td>
<td>$15.17</td>
<td>-0.014</td>
<td>-0.013</td>
<td>0.006</td>
<td>-0.032</td>
</tr>
<tr>
<td>Real US Pig Iron P</td>
<td>$18.40</td>
<td>-0.014</td>
<td>-0.017</td>
<td>0.015</td>
<td>-0.032</td>
</tr>
<tr>
<td>Real UK Pig Iron P</td>
<td>$11.58</td>
<td>0.005</td>
<td>-0.002</td>
<td>0.057</td>
<td>-0.030</td>
</tr>
<tr>
<td>Real GNP/Capita</td>
<td>$143.65</td>
<td>0.022</td>
<td>0.013</td>
<td>0.024</td>
<td>0.032</td>
</tr>
<tr>
<td>Manufacturing/GNP</td>
<td>0.211</td>
<td>-0.002</td>
<td>0.010</td>
<td>-0.006</td>
<td>-0.015</td>
</tr>
<tr>
<td>Urban/Population</td>
<td>0.295</td>
<td>0.021</td>
<td>0.025</td>
<td>0.009</td>
<td>0.025</td>
</tr>
<tr>
<td>Gross I/GNP</td>
<td>0.144</td>
<td>0.017</td>
<td>0.004</td>
<td>-0.008</td>
<td>0.058</td>
</tr>
<tr>
<td>Effective Tariff</td>
<td>0.177</td>
<td>0.010</td>
<td>0.113</td>
<td>0.002</td>
<td>-0.062</td>
</tr>
<tr>
<td>Liverpool→Hamilton</td>
<td>$6.39</td>
<td>-0.015</td>
<td>-0.026</td>
<td>-0.029</td>
<td>0.015</td>
</tr>
<tr>
<td>Pittsburgh→Hamilton</td>
<td>$1.62</td>
<td>-0.021</td>
<td>-0.038</td>
<td>-0.013</td>
<td>-0.002</td>
</tr>
<tr>
<td>Marquette→Hamilton</td>
<td>$4.40</td>
<td>-0.032</td>
<td>-0.042</td>
<td>-0.017</td>
<td>-0.029</td>
</tr>
<tr>
<td>Connelsville→Hamilton</td>
<td>$3.40</td>
<td>-0.021</td>
<td>-0.038</td>
<td>-0.013</td>
<td>-0.002</td>
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</table>

Note: Definitions and series composition described in text. Detailed construction and source information provided in the Data Appendix: http://qed.econ.queensu.ca/faculty/keayi/datalinks/irondataapp.pdf. 1890 quantities reported in net tons of pig iron and person-days, values reported in 1890 CAD. Effective protection reported as *ad valorem* rate.
Table 2: Econometric Results from Aggregate Demand-Supply Model

<table>
<thead>
<tr>
<th>Dependent Variable: Aggregate Q</th>
<th>OLS</th>
<th>Levels</th>
<th>IV: GLS</th>
<th>First Differences</th>
<th>OLS</th>
<th>Levels</th>
<th>IV: GLS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 1</td>
</tr>
<tr>
<td>Foreign P</td>
<td>-0.084 (0.835)</td>
<td>-0.884 (0.009)</td>
<td>0.455 (0.022)</td>
<td>0.585 (0.046)</td>
<td>0.609 (0.114)</td>
<td>0.550 (0.207)</td>
<td>0.663 (0.318)</td>
</tr>
<tr>
<td>US P</td>
<td>0.180 (0.773)</td>
<td>0.378 (0.486)</td>
<td>0.000 (0.017)</td>
<td>0.369 (0.369)</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
</tr>
<tr>
<td>UK P</td>
<td>-0.687 (0.070)</td>
<td>-0.905 (0.017)</td>
<td>0.487 (0.233)</td>
<td>0.659 (0.164)</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
</tr>
<tr>
<td>Protection</td>
<td>0.853 (0.059)</td>
<td>1.015 (0.018)</td>
<td>0.487 (0.233)</td>
<td>0.659 (0.164)</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
</tr>
<tr>
<td>Tariff</td>
<td>0.562 (0.005)</td>
<td>0.639 (0.000)</td>
<td>-0.400 (0.114)</td>
<td>1.734 (0.002)</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
</tr>
<tr>
<td>Transport</td>
<td>-0.763 (0.013)</td>
<td>-0.390 (0.191)</td>
<td>0.463 (0.189)</td>
<td>0.400 (0.246)</td>
<td>0.463 (0.246)</td>
<td>0.463 (0.246)</td>
<td>0.463 (0.246)</td>
</tr>
<tr>
<td>Domestic D</td>
<td>1.912 (0.000)</td>
<td>2.266 (0.000)</td>
<td>2.061 (0.000)</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
</tr>
<tr>
<td>L Cost</td>
<td>-0.962 (0.000)</td>
<td>-0.713 (0.000)</td>
<td>-1.303 (0.000)</td>
<td>-0.354 (0.000)</td>
<td>-1.377 (0.000)</td>
<td>-1.377 (0.000)</td>
<td>-1.377 (0.000)</td>
</tr>
<tr>
<td>M Cost</td>
<td>-1.216 (0.033)</td>
<td>-0.818 (0.106)</td>
<td>-0.008 (0.981)</td>
<td>-1.727 (0.981)</td>
<td>-0.008 (0.981)</td>
<td>-1.727 (0.981)</td>
<td>-1.727 (0.981)</td>
</tr>
<tr>
<td>Coke Cost</td>
<td>-1.778 (0.011)</td>
<td>-1.681 (0.007)</td>
<td>-1.681 (0.007)</td>
<td>0.418 (0.217)</td>
<td>-0.002 (0.998)</td>
<td>-0.002 (0.998)</td>
<td>-0.002 (0.998)</td>
</tr>
<tr>
<td>Ore Cost</td>
<td>1.458 (0.003)</td>
<td>1.643 (0.000)</td>
<td>1.643 (0.000)</td>
<td>-0.217 (0.483)</td>
<td>0.243 (0.586)</td>
<td>0.243 (0.586)</td>
<td>0.243 (0.586)</td>
</tr>
<tr>
<td>Constant</td>
<td>1.634 (0.411)</td>
<td>0.889 (0.594)</td>
<td>-5.611 (0.006)</td>
<td>0.080 (0.094)</td>
<td>0.000 (0.138)</td>
<td>0.000 (0.138)</td>
<td>0.000 (0.138)</td>
</tr>
<tr>
<td>F or χ² Stat</td>
<td>42.45 (0.000)</td>
<td>54.32 (0.000)</td>
<td>217.62 (0.000)</td>
<td>4.95 (0.000)</td>
<td>25.21 (0.000)</td>
<td>40.38 (0.000)</td>
<td>40.38 (0.000)</td>
</tr>
<tr>
<td>Robust SE</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hausman</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Weak Inst</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sargan</td>
<td>44</td>
<td>44</td>
<td>43</td>
<td>43</td>
<td>42</td>
<td>42</td>
<td>42</td>
</tr>
</tbody>
</table>

Note: P-values are reported in parentheses, and statistically significant parameter estimates are reported in bold. All variables are measured as natural logarithms. The reported parameter estimates, therefore, refer to elasticities. All variables are measured relative to Canadian aggregates: Aggregate Q and Domestic D relative to GNP; Protection, Tariff, Transport, L Cost, M Costs relative to WPI. Foreign P, Transport, M Costs are assumed to be exogenous. Instruments for Protection and Tariff include: US pig iron duties, US and UK pig iron output. Instruments for Domestic D include: US and UK domestic saving rates. Instruments for L Cost include: US and UK real wages, US immigration rates, UK emigration rates. Hausman specification tests identify the presence of endogeneity. Weak instrument tests identify jointly insignificant instruments. Sargan over-identification tests identify instrument exogeneity.
### Table 3a: Econometric Results from (Stage 1) Heckman Selection Model (with Furnace Level Micro-Data)

<table>
<thead>
<tr>
<th>Dependent: Entry (Q&gt;0)</th>
<th>Probit Model 3</th>
<th>Probit Model 4</th>
<th>IV Probit: GLS Model 3</th>
<th>IV Probit: GLS Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># Furnaces t-1</td>
<td>0.137</td>
<td>0.097</td>
<td>-0.015</td>
<td>-0.042</td>
</tr>
<tr>
<td></td>
<td>(0.087)</td>
<td>(0.307)</td>
<td>(0.485)</td>
<td>(0.051)</td>
</tr>
<tr>
<td>Aggregate Q t-1</td>
<td>-1.205</td>
<td>-1.429</td>
<td>-0.329</td>
<td>-0.364</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Average Age t-1</td>
<td>-0.012</td>
<td>-0.017</td>
<td>-0.004</td>
<td>-0.003</td>
</tr>
<tr>
<td></td>
<td>(0.440)</td>
<td>(0.335)</td>
<td>(0.084)</td>
<td>(0.187)</td>
</tr>
<tr>
<td>Foreign P</td>
<td>-1.225</td>
<td>-0.352</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US P</td>
<td>-1.216</td>
<td></td>
<td>-0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.094)</td>
<td></td>
<td>(0.995)</td>
<td></td>
</tr>
<tr>
<td>UK P</td>
<td>-0.885</td>
<td></td>
<td>-0.357</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.107)</td>
<td></td>
<td>(0.000)</td>
<td></td>
</tr>
<tr>
<td>Protection</td>
<td>1.033</td>
<td>0.203</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.076)</td>
<td>(0.066)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tariff</td>
<td>0.684</td>
<td></td>
<td>0.135</td>
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</tr>
<tr>
<td></td>
<td>(0.029)</td>
<td></td>
<td>(0.002)</td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>-0.041</td>
<td></td>
<td>-0.034</td>
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<tr>
<td></td>
<td>(0.930)</td>
<td></td>
<td>(0.675)</td>
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<tr>
<td>Domestic D</td>
<td>1.079</td>
<td>1.752</td>
<td>0.373</td>
<td>0.610</td>
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<td></td>
<td>(0.082)</td>
<td>(0.036)</td>
<td>(0.001)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>L Cost</td>
<td>-0.718</td>
<td>-0.636</td>
<td>-0.428</td>
<td>-0.422</td>
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<td></td>
<td>(0.004)</td>
<td>(0.018)</td>
<td>(0.000)</td>
<td>(0.000)</td>
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<tr>
<td>M Cost</td>
<td>-0.853</td>
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<td>0.110</td>
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<td>(0.058)</td>
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<td>(0.335)</td>
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<tr>
<td>Coke Cost</td>
<td>-1.994</td>
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<td>-0.570</td>
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<tr>
<td></td>
<td>(0.063)</td>
<td></td>
<td>(0.001)</td>
<td></td>
</tr>
<tr>
<td>Ore Cost</td>
<td>2.012</td>
<td></td>
<td>0.492</td>
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<tr>
<td></td>
<td>(0.005)</td>
<td></td>
<td>(0.000)</td>
<td></td>
</tr>
<tr>
<td>K Cost</td>
<td>0.040</td>
<td>0.019</td>
<td>0.006</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>(0.381)</td>
<td>(0.637)</td>
<td>(0.518)</td>
<td>(0.754)</td>
</tr>
<tr>
<td>Market Share t-1</td>
<td>-0.992</td>
<td>-1.016</td>
<td>-0.207</td>
<td>-0.208</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Constant</td>
<td>-1.923</td>
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<td>-0.787</td>
<td>-0.159</td>
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<tr>
<td></td>
<td>(0.349)</td>
<td>(0.319)</td>
<td>(0.094)</td>
<td>(0.711)</td>
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<tr>
<td>Wald or $\chi^2$ Stat</td>
<td>121.49</td>
<td>198.41</td>
<td>778.36</td>
<td>829.99</td>
</tr>
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<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
</tbody>
</table>

Note: P-values are reported in parentheses, and statistically significant parameter estimates are reported in bold. All variables are measured as natural logarithms, relative to Canadian aggregates: Aggregate Q and Domestic D relative to GNP; Protection, Tariff, Transport, L, M and K Costs relative to WPI. Instruments for Protection and Tariff include: US pig iron duties, US and UK pig iron output. Instruments for Domestic D include: US and UK domestic saving rates. Instruments for L Cost include: US and UK real wages, US immigration rates, UK emigration rates. Hausman specification tests identify the presence of endogeneity. Weak instrument tests identify jointly insignificant instruments. Sargan over-identification tests identify instrument exogeneity.
Table 3b: Econometric Results from (Stage 2) Heckman Selection Model (with Furnace Level Micro-Data)

<table>
<thead>
<tr>
<th>Dependent: Furnace Q</th>
<th>ML IV: GLS</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Model 3</td>
</tr>
<tr>
<td>Foreign P</td>
<td>0.271</td>
</tr>
<tr>
<td></td>
<td>(0.286)</td>
</tr>
<tr>
<td>US P</td>
<td>-0.452</td>
</tr>
<tr>
<td></td>
<td>(0.394)</td>
</tr>
<tr>
<td>UK P</td>
<td>-0.356</td>
</tr>
<tr>
<td></td>
<td>(0.323)</td>
</tr>
<tr>
<td>Protection</td>
<td>1.153</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
</tr>
<tr>
<td>Tariff</td>
<td>0.696</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
</tr>
<tr>
<td>Transport</td>
<td>-0.351</td>
</tr>
<tr>
<td></td>
<td>(0.176)</td>
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<tr>
<td>Domestic D</td>
<td>1.185</td>
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<tr>
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<td>(0.000)</td>
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<tr>
<td>L Cost</td>
<td>-0.577</td>
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<td></td>
<td>(0.002)</td>
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<tr>
<td>M Cost</td>
<td>-1.852</td>
</tr>
<tr>
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<td>(0.000)</td>
</tr>
<tr>
<td>Coke Cost</td>
<td>-0.093</td>
</tr>
<tr>
<td></td>
<td>(0.912)</td>
</tr>
<tr>
<td>Ore Cost</td>
<td>-0.008</td>
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<tr>
<td></td>
<td>(0.988)</td>
</tr>
<tr>
<td>Constant</td>
<td>-1.193</td>
</tr>
<tr>
<td></td>
<td>(0.595)</td>
</tr>
</tbody>
</table>

Wald or χ² Stat: 121.49 (0.000) 198.41 (0.000) 111.01 (0.000) 101.87 (0.000)

Robust SE: ✓ ✓ ✓ ✓
Cluster: Year: ✓ ✓ ✓ ✓
FE: Furnace: ✓ ✓ ✓ ✓
Hausman: ✓ ✓ ✓ ✓
Weak Inst: ✓ ✓ ✓ ✓
Sargan: ✓ ✓ ✓ ✓

N_Total: 572 572 572 572
N_Q>0: 232 232 232 232

Note: P-values are reported in parentheses, and statistically significant parameter estimates are reported in bold. All variables are measured as natural logarithms, relative to Canadian aggregates: Furnace Q and Domestic D relative to GNP; Protection, Tariff, Transport, L and M Costs relative to WPI. Instruments for Protection and Tariff include: US pig iron duties, US and UK pig iron output. Instruments for Domestic D include: US and UK domestic saving rates. Instruments for L Cost include: US and UK real wages, US immigration rates, UK emigration rates. Hausman specification tests identify the presence of endogeneity. Weak instrument tests identify jointly insignificant instruments. Sargan over-identification tests identify instrument exogeneity.
Figures

Figure 1a: Canadian Pig Iron Output

Figure 1b: 19th Century Canadian Pig Iron Output
Figure 2: Canadian Market Shares for Pig Iron

Figure 3: Entry and Exit of Canadian Blast Furnaces
Figure 8: Counterfactual Pig Iron Output / Predicted Pig Iron Output