Trade policy and industrial development: iron and steel in a small open economy, 1870–1913

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Abstract. In this paper we argue that effective tariff protection associated with the 1879 National Policy and the 1887 Tupper tariffs triggered investment in new, technologically advanced blast furnaces that were capable of accommodating rapid output expansion. This conclusion is based on an appreciation of the timing of late nineteenth-century investments in Canada and their connection to changes in government policy and other demand determinants. In our empirical investigation we use new information on west-bound transatlantic freight rates, intra-continental transport costs, and furnace-specific micro-data, and we acknowledge the endogenous relationships linking investment to domestic demand, labour costs, and tariffs. JEL classification: N71

Politique commerciale et développement industriel : fer et acier dans une petite économie ouverte, 1870–1913. Dans ce texte, les auteurs suggèrent que la protection tarifaire effective, associée à la Politique Nationale de 1879 et aux tarifs de Tupper de 1887, ont déclenché des investissements dans de nouveaux hauts fourneaux technologiquement sophistiqués capables de s’ajuster à l’expansion rapide des taux de production. Cette conclusion est fondée sur une appréciation du moment des investissements au Canada à la fin du 19ème siècle, et de leur connexion aux changements dans la politique gouvernementale, et aux autres déterminants de la demande. Cette enquête empirique utilise des renseignements inédits sur les taux de fret du transport transatlantique vers l’ouest, les coûts de transport intracontinental, et des micro-données sur les hauts fourneaux. On reconnaît les relations

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The authors wish to thank two anonymous referees for their contributions. Seminar participants at UBC, Social Science History Association Conference, Center for the Evolution of the Global Economy Conference, and Canadian Economics Association Conference provided helpful suggestions. Kris Inwood gratefully acknowledges financial support provided by SSHRC grant #410–1999–0672. Ian Keay gratefully acknowledges financial support provided by SSHRC grant #410–2007–0323. All errors and omissions remain the responsibility of the authors.

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endogènes entre l’investissement, et la demande domestique, les coûts du travail, ainsi que les tarifs.

1. 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 potential for 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.

Between 1870 and 1913 the Canadian economy accomplished exactly this task – constructing large, modern and efficient blast furnaces that came to supply virtually the entire domestic market in the face of intense British and American competition. This case of industrial development raises two questions. First, how do we account for the expansion of the Canadian iron industry in a market with low and falling prices for British and American imports? And, more generally, how different would the Canadian economy have been in the absence of a domestic primary iron and steel industry? The first question is challenging because during the late nineteenth and early twentieth centuries the Canadian manufacturing sector was developing in a complex and fluid technological and economic environment. Any effort to explain the development patterns we observe is complicated by this dynamism. We attempt to discriminate among the forces acting on Canadian producers by allowing for the possibility that technological transformation and output expansion responded to coincident and interdependent changes in trade policy, transportation costs, domestic and international demand, and input supply conditions. Finding a satisfactory answer to the second question, even though it is clearly important for the formation of policy prescriptions or welfare conclusions, imposes empirical demands that are, unfortunately, largely beyond the scope of this paper.¹

We are particularly interested in the influence of government policy on the development of the Canadian iron and steel industry. Like other Atlantic

¹ Although we report dead weight loss estimates in the technical appendix (available from the Canadian Journal of Economics online archive at cje.economics.ca), our analysis is narrowly focused with respect to the broader general equilibrium effects of tariff protection. However, our findings provide information that would be necessary for any consideration of these broader issues.
economies, Canada restructured and refocused its trade policy towards protectionism during this period. Under the National Policy in 1879 and the Tupper tariffs in 1887, effective protection for pig iron rose sharply. More generally, trade policy and the possibility of reciprocity with the United States played an important role in every Canadian federal election from 1867 until the First World War (Beaulieu and Emery 2001; Dales 1966; Forster 1986; McDiarmid 1949). And yet, there remains substantial uncertainty about the impact of the National Policy’s tariffs on industrial development in general (Dales 1966, 1979; Harris and Lewis 1992), and on the iron and steel industry in particular (Donald 1915). At least part of this uncertainty stems from the confounding effects of chronologically coincident forces that were occurring within the Canadian economy during this period.

We revisit the tariff question with the help of a partial equilibrium demand and supply model developed by Grossman (1986) and used by Davis and Irwin (2008) to investigate the factors underlying the early expansion of the US pig iron industry. The model provides a framework for estimating the sensitivity of domestic producers to changing conditions within their domestic and international markets, input supply shocks, falling transportation costs, and changes in 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. The estimation uses new data on intra and inter-continental transportation costs and micro-data on production and employment from individual blast furnaces.²

We find that the relationships linking pig iron production to domestic and international demand, transport costs, supply conditions, and tariff protection could be both subtle and transient. In general, raw material costs, capital costs, and international demand appear to have had weak and variable connections to firms’ production decisions. Because reductions in water and rail transport costs affected both input costs and the price of imported pig iron, the net effect of falling transport costs was also weak and variable. Specifications using a linear spline and tests for parameter stability indicate that at different stages during the 1870–1913 period domestic demand and labour costs had strong connections to production decisions. However, it is effective tariff protection that appears to have been consistently strongly and positively correlated to the quantity of pig iron produced by Canadian blast furnaces. Results from jointly estimated Heckman selection models using furnace-specific micro-data on output and entry-and-exit are consistent with our view that increases in the pig iron tariff in 1879 and 1887 encouraged industry turnover, which facilitated a technological transformation from small-rural-charcoal-fuelled blast furnaces to larger-modern-coke-burning furnaces.

² A complete description of the construction, composition, and sources for all data series used in this paper is included in the technical appendix, available from the Canadian Journal of Economics online archive (cje.economics.ca).
We conclude that between 1870 and 1913 effective tariff protection was positively related to the development of the Canadian iron industry, but this relationship weakened as rising domestic demand and, in a more transient fashion, falling labour costs came to play important roles. During the 1880s and early 1890s the federal government’s commitment to tariff protection was an important trigger for irreversible investments in new, technologically advanced blast furnaces that were capable of accommodating the dramatic expansion of domestic output that took hold during the late nineteenth century.

2. Development patterns: producing pig iron in a small open economy

The transformative expansion of many Atlantic economies during the last decades of the nineteenth century has prompted efforts to understand the causes and consequences of differential performance across nations and industries during this period (O’Rourke and Williamson 1999). The macroeconomic effects associated with declining ocean freight rates (Harley 1980, 1988, 1989), expanding railway networks (Fogel 1964; Hawke and Higgins 1981; Lewis 1981; Norrie 1974), resource exploitation (Donald 1915; Prentice 2010; Wright 1990) and changing trade policies (Irwin 2000a, b; Lehmann and O’Rourke 2011; Schularick and Solomou 2011; Taussig 1931) have been extensively documented. Because iron and steel industries were large and influential technological leaders, they have been used to probe specific aspects or examples of market expansion and technological advance stemming from these changes (Allen 1977; Burn 1961; Davis and Irwin 2008; Evans and Ryden 2005; Inwood 1987; Temin 1964; Warren 1970, 1973). Remarkably few of these studies have acknowledged the interdependence and endogeneity of market expansion, land and ocean transport costs, trade policy, and industrial development (Redding and Strum 2008; Donaldson and Hornbeck 2012).

The complexities associated with late nineteenth- and early twentieth-century development were certainly present in the Canadian economic environment in which a modern, efficient, and competitive primary iron and steel industry evolved. By 1900 expanding iron ore exports from Newfoundland and new ore discoveries in northern Ontario provided increasing supplies of domestic raw materials (Donald 1915; Inwood 1983, 1987). At exactly this time, a boom in Canadian immigration levels, western settlement and construction swept incomes, investment, and productivity upwards at an unprecedented rate (Green and Urquhart 1987; Inwood and Stengos 1991). Beginning in the 1870s and accelerating through the 1880s and 1890s, intra-national and international migration contributed to the growth of the prairie provinces and the cities in the east (Drummond 1987; Green and Green 1993; Green and MacKinnon 2001). Transportation networks were also changing significantly. 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 brokerage fees declined sharply from their early nineteenth-century peaks (Cruikshank 1987; Fishlow 1966; Laurent 1983; Williamson 1977). Amidst all these changes, industrial and trade policy evolved in its highly politicized way. Clearly, the years from 1870 to 1913 embodied a significant restructuring of the Canadian economy, and this restructuring strongly affected the iron industry.

When Ontario, Quebec, Nova Scotia, and New Brunswick formed the Dominion of Canada in 1867, over half of all pig iron consumed in Canada was imported, and domestic production levels were flat (Inwood 1986a, b). Pig iron smelted in Quebec with traditional charcoal fuels struggled to compete with increasingly inexpensive British imports. Nova Scotia’s solitary coke furnace was intermittently bankrupt throughout the 1870s and 1880s. Even in Ontario, the emerging centre of industrial power in Canada, there was little pig iron production until the 1890s. Despite all this, by 1900 new technologically advanced blast furnaces had been blown in at Hamilton, Deseronto, and Midland in Ontario, and Pictou and Sydney in Nova Scotia. By 1913, on the eve of Canada’s entry into the First World War, rapidly expanding steel production at Hamilton, Sault Ste Marie, and Sydney accounted for more than half of all primary iron and steel tonnage, domestic pig iron production was 120 times what it had been in 1870 and 50 times higher than 1890 levels, and imports had fallen to one-tenth of all Canadian pig iron consumption (Donald 1915; Inwood 1987). The large mills operating in Sydney, Hamilton, and Sault Ste Marie were taking advantage of the scale economies associated with continuous operation and contiguity among blast furnaces, steel furnaces, and rolling mills, which had become hallmarks of international technological leadership.

This transformation was not instantaneous. Using information recorded in the Geological Survey of Canada’s annual census of mining industries and, before 1887, reports in trade journals, newspapers, archival letters, and various government and non-governmental studies, we have reconstructed annual output, employment, and labour productivity figures for each of the 13 blast furnaces that were in operation in Canada between 1870 and 1913. This establishment-level 3 The Geological Survey of Canada (GSC) enumerated all mining establishments on an annual basis beginning in 1886. These returns survive in manuscript form at Library and Archives Canada. Between 1871 and 1885 GSC collected basic production information on a less systematic basis (Harrington 1974). Much of this survives in notes, a draft industry history prepared by Robert Bell, and in the mining schedule of the 1871 census. A number of collections at the Public Archives of Nova Scotia provide additional detail. The economic importance of this industry also attracted considerable discussion in newspapers and trade journals of the period (Bartlett 1884). For more information see Inwood (1986) or Hardy (1995).
4 The panel of Canadian blast furnaces includes five from Quebec: St Maurice (1738–1882), L’Islet (1798–1877), Radnor (1860–1910), St Francis (1869–1877), and Drummondville (1869–1911); three from Nova Scotia: Londonderry (1848–1908), Pictou (1892–1913), and Sydney (1901–1913); and five from Ontario: Hamilton (1896–1913), Deseronto (1899–1913), Midland (1900–1913), Sault Ste Marie (1904–1913), and Port Arthur/Port Colborne (1907–1913). A map showing the location of all furnaces and US raw material supply points is included in the technical appendix, available from the Canadian Journal of Economics online archive (cje.economics.ca).
### TABLE 1
Canadian iron industry: output, input prices, demand, and protection

<table>
<thead>
<tr>
<th></th>
<th>Levels</th>
<th>Average annual% Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1870</td>
<td>1913</td>
</tr>
<tr>
<td>Production</td>
<td>6776</td>
<td>1118224</td>
</tr>
<tr>
<td>$Q$/real GNP</td>
<td>17.72</td>
<td>543.78</td>
</tr>
<tr>
<td>Labour hours</td>
<td>47513</td>
<td>513 889</td>
</tr>
<tr>
<td>Market share</td>
<td>0.746</td>
<td>0.849</td>
</tr>
<tr>
<td>$Q$/L</td>
<td>0.143</td>
<td>3.238</td>
</tr>
<tr>
<td>Real WK</td>
<td>0.022</td>
<td>0.017</td>
</tr>
<tr>
<td>Real WM</td>
<td>$18.32</td>
<td>$10.10</td>
</tr>
<tr>
<td>Real WL</td>
<td>$0.30</td>
<td>$0.47</td>
</tr>
<tr>
<td>Real US pig iron price</td>
<td>$24.38</td>
<td>$13.65</td>
</tr>
<tr>
<td>Real UK pig iron price</td>
<td>$9.62</td>
<td>$11.68</td>
</tr>
<tr>
<td>Transport costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stockton→Hamilton</td>
<td>$11.64</td>
<td>$5.73</td>
</tr>
<tr>
<td>Pittsburgh→Hamilton</td>
<td>$3.85</td>
<td>$1.43</td>
</tr>
<tr>
<td>Marquette→Hamilton</td>
<td>$8.93</td>
<td>$2.52</td>
</tr>
<tr>
<td>Connelsville→Hamilton</td>
<td>$8.20</td>
<td>$3.05</td>
</tr>
<tr>
<td>Real GNP/capita</td>
<td>$105.53</td>
<td>$269.44</td>
</tr>
<tr>
<td>Gross investment/GNP</td>
<td>0.157</td>
<td>0.328</td>
</tr>
<tr>
<td>Effective tariff</td>
<td>0</td>
<td>0.092</td>
</tr>
</tbody>
</table>

NOTES: Detailed construction and source information are included in the technical appendix, available from the Canadian Journal of Economics online archive (cje.economics.ca). Quantities are reported in net tons of pig iron and person-days; average annual percentage changes are calculated as log-differences; production relative to real GNP are reported in net tons per million 1890 CAD; prices and transport costs are reported in 1890 CAD; effective protection is reported as ad valorem rate.

data reveal that much of the industry turnover, output growth, and productivity improvement began to take hold well before 1900.

In table 1 we report net tons (2,000 lbs) of pig iron produced in 1870 and 1913 and annual percentage changes in pig iron production relative to real gross national product (GNP) averaged over the years 1870–1913, and the sub-periods 1870–1889, 1890–1900, and 1901–1913. Although output expanded rapidly over the entire period, relative growth accelerating across each sub-period, production was initially stagnant, before slowly accelerating at the very end of the 1870s and into the early 1880s. Tests for structural breaks in the series linear trend confirm the presence of discontinuities in 1890 and 1900.

5 To control for aggregate scale effects and to focus on industry-specific rather than macroeconomic relationships, all variables are measured relative to the aggregate economy. Figures depicting annual pig iron production over the 1870–1913 and 1870–1900 periods are included in the technical appendix, available from the Canadian Journal of Economics online archive (cje.economics.ca).

6 These changes in production reflect growth within existing firms and the entry of new, larger coke-burning mills. More detailed information and a figure depicting annual entry and exit is included in the technical appendix, available from the Canadian Journal of Economics online archive (cje.economics.ca).
Employment figures reported in table 1 for 1870 and 1913 represent the number of person days in blast for all furnaces in operation. Across the three sub-periods we see a pattern in employment that, although more volatile, is similar to the pattern in output – slow growth beginning in and around 1880, accelerating, and persistent increases taking hold during the 1890s and early 1900s.

The share of the domestic market supplied by Canadian blast furnaces declined sharply during the first half of the 1870s before stabilizing at approximately 35% over the next decade and a half. Starting in the early 1890s, domestic producers’ market share began to increase in a sustained trajectory from 34% in 1890 to nearly 90% in 1900. Having captured virtually the entire home market, domestic producers maintained their dominant position until the start of the First World War. From table 1 we can also see that these movements in domestic producers’ market share are closely correlated to movements in their labour productivity performance. Aggregate net tons of pig iron produced per person-day in blast grew by more than 8% per year before 1890 and more than 9% per year after 1900, but stagnated during the 1890s as the new blast furnaces expanded employment at almost the same rate as output.

In general, the summary statistics reported in table 1 tell a consistent story of industrial development over the 1870–1913 period. The Canadian iron industry was stagnant through most of the 1870s, before experiencing the beginnings of a turnaround early in the 1880s, accelerating growth after 1890, and finally dramatic expansion after the turn of the twentieth century. Because this development was occurring in a particularly complex and fluid environment, any explanation for it must cast a wide net in an effort to capture the full range of forces capable of influencing the industry’s investment and production patterns.

3. The forces affecting development: potential explanations

The proximate cause of the output expansion that began in the 1880s was new investment and industry turnover that favoured larger, modern, more technologically advanced mills. This observation is not particularly enlightening, however, unless we can determine why these new investments occurred when and where they did. In this section we review the forces that had the potential to affect investment decisions, in order to frame a systematic, quantitative evaluation of the potential explanations for the observed development patterns.

New investment arises from a change in the cost and/or availability of funds or a change in the likely returns to the investment. Blast furnaces have always been capital-intensive and potentially risky undertakings. However, during the late nineteenth century, retained earnings and local capital markets, rather than...
arms-length investment through sophisticated financial intermediation, were the most important sources of financial capital for Canadian producers (Inwood 1986b, 1987; Keay and Redish 2004; Kilbourn 1960). The available evidence on Canadian capital costs indicates that these costs were virtually flat through the 1870–1913 period.\(^8\) Holding all else constant, stable capital prices cannot explain a sudden burst of new investment. This leads us to focus on improvements in the returns to investment in response to changes in supply conditions, including learning-by-doing, raw material costs and labour costs, and/or demand conditions, including international demand, domestic demand and effective protection.

Raw material costs clearly were important. About 1.75 tons of iron ore and 1.25 tons of coke were needed to produce one ton of pig iron. These two inputs alone accounted for approximately two-thirds of the value of a ton of pig iron. Donald (1915) has argued that the discovery of iron ore in northern Ontario and Newfoundland explains the important capacity-expanding investments. This explanation is consistent with a traditional ‘resource dependent’ view of Canadian industrial development (Watkins 1963), but after some consideration, it is not as compelling as it initially seems. One of the ‘resource discoveries’ cited by Donald was not a discovery at all – the Newfoundland ore deposit had been known since the seventeenth century and had been exploited on previous occasions (Inwood 1983, 1986a).\(^9\) The second ore deposit Donald identifies, in northern Ontario, was genuinely discovered in 1898 as an unanticipated by-product of a gold rush, but the Ontario furnaces never used ore from this mine (Inwood 1987).

Of course, even if there was no discovery-driven shift in raw material costs, the importance of raw materials in production implies that all changes in ore and coke prices may influence investment and output decisions. The 1870 and 1913 raw material prices reported in table 1 (WM) are a weighted average of US iron ore prices at the mine-head in Marquette, MI, plus the cost to transport the ore from the mine to Hamilton, ON, and US coke prices at the kilns in Connelsville, PA, plus tariffs and the cost to transport the coke to Hamilton, ON, deflated by a Canadian wholesale price index (WPI). The inputs are weighted by blast furnace input intensities reported in the 1880–1910 United States manufacturing census.\(^10\) Canadian blast furnaces’ 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.

\(^8\) The only Canadian capital cost figures available for this period are long-term government bond yields, which vary between a high of 5% (in nominal terms) in 1870 and a low of 2.8% in 1897. Government bond yields do not perfectly reflect blast furnaces’ capital costs, but they are not wildly inappropriate, because government policy was structured to suppress risk faced by industry investors.

\(^9\) Canadian furnaces did use Newfoundland ore during the 1890s, but this appears to be a response to developments within the North American ore market, rather than an exogenous discovery effect.

\(^10\) These weights correspond closely to raw material ‘yields’ reported for US blast furnaces in Allen (1978, notes to appendix table 2).
After raw materials, the next most costly input was labour. We do not have access to systematic information on hourly or weekly wages for individual blast furnaces or occupations, but aggregate primary iron and steel wage and salary data are available (Urquhart 1993). We use the industry information with our furnace-specific employment series (deflated by a Canadian WPI) to derive an index of average real earnings per person-day. The average annual rates of change for labour remuneration reported in table 1 reveal slowly rising pay through the 1870s and 1880s, followed by more stable, but falling wages throughout the post-1890 period. The decline in remuneration during the last half of our sample period reflects a reduction in aggregate wages and salaries and a simultaneous increase in the number of person-days in blast. The rather abrupt nature of the decline (particularly after 1900) suggests that labour supply responses, which we typically assume to be much more gradual, are unlikely to be an exogenous cause. It is more likely that some organizational or technological aspect of the new furnaces drove this reduction in average wages per day.\footnote{Intriguing possible explanations include deskilling technological change (Acemoglu 1998; Goldin and Katz 1998) or skill and/or industry-specific migration policies (Green and Green 2004).}

Changes in international demand may have influenced Canadian investment and production decisions through their effect on import prices. Pig iron prices in the United States and Britain (expressed in 1890 Canadian dollars per net ton) and average annual rates of change for these prices are reported in table 1. US prices in 1870 were well above those charged by their UK counterparts, but as has been extensively documented, the British competitive advantage would not last. Price movements in both nations were similar – US and British prices fell during the 1870s, 1880s, and after 1900, and both nations’ prices rose during the 1890s – but the decline in British prices during the early period was modest and the subsequent increase during the 1890s was sharp. US prices, in contrast, fell on average over the entire period, rates of decline during the first and last sub-periods were steep, and price increases during the 1890s were modest. 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, but they are not obviously coincident with Canadian investment patterns.

Of course, the price for pig iron in foreign markets is only one factor affecting the price of imports in the Canadian market. We must also consider transport costs. Primarily due to rapid technological change in the transport sector between 1870 and 1913, trans-oceanic freight costs provided significant but declining protection for those producing goods that were traded on international markets. Using evidence on the cost to ship pig iron from British to North American ports, reported monthly in the industry periodical \textit{Iron Age}, we have compiled a new west-bound transatlantic freight rate series that spans our period of study. We combine these freight rates with estimates of rail charges to and from port facilities, brokerage fees, wharfage charges, and insurance premiums to derive
annual estimates of the total cost to move a net ton of pig iron from blast furnaces in northeastern England to Hamilton. We have also collected North American rail rates per ton-mile; loading charges and insurance for pig iron, coke, and ore; as well as freight rates for the movement of ore from upper (Marquette, MI) to lower (Buffalo, NY) Great Lakes ports. The 1870 and 1913 UK-to-Hamilton and Pittsburgh-to-Hamilton total transport costs for a net ton of pig iron (in 1890 CAD) and average annual rates of change are reported in table 1. We also report the total transport costs (per net ton of pig iron) for the movement of ore from Marquette-to-Hamilton and coke from Connelsville-to-Hamilton.

Canadian blast furnaces’ transatlantic and intra-continental transport protection was falling sharply through the late nineteenth century, but the rate of decline slowed and ocean freight rates actually rose slightly after 1900 (in real terms). As a result of technological improvements in rail, port operations, and Great Lake steamers’ fuel efficiency, shipping costs for ore and coke fell rapidly throughout the 1870–1913 period (Allen 1977; Cruikshank 1987; Fishlow 1966; Laurent 1983; Williamson 1977). About two-thirds of the transport cost savings associated with raw material inputs were made in the overland transport of coke, and the remainder arises from a dramatic fall in the cost of ore carriage on the Great Lakes. Because the transport component of raw material costs declined more than the freight on imported pig iron, particularly after 1900, the net impact of transportation improvements was to increase effective protection available to Canadian blast furnaces.

Domestic demand, of course, is another potential influence. Davis and Irwin (2008, 265) argue against the use of typical macroeconomic indicators such as aggregate income, income per capita, or population to measure changes in the size of the US pig iron market. A more targeted measure is required, they argue, because iron and steel products were used to produce machinery, transportation equipment, building materials, and all forms of infrastructure and investment goods. Accordingly, Davis and Irwin use industrial production (less iron and steel output) to proxy nineteenth-century domestic demand for US pig iron. The dramatic demographic changes experienced in Canada during this period suggest that there may be a need to consider additional demand determinants such as urbanization, western settlement, railway building, or simply net migration. Because each of these determinants captures some contributing factor, or particular segment of the market for investment goods in Canada, we settle on aggregate fixed capital accumulation (gross investment) as our proxy for domestic demand. In table 1 we report average annual rates of change for real income per capita and the share of gross investment in GNP. The chronological patterns for these measures are similar – domestic demand for pig iron appears to have grown modestly

12 The new transport cost estimates, along with source and construction details, are included in the technical appendix, available from the Canadian Journal of Economics online archive (cje.economics.ca).

13 This pattern in transatlantic transport costs for pig iron is consistent with Persson’s (2004) estimates for east-bound wheat shipments.
during the 1870s and early 1880s, slowing during the last half of the 1880s before accelerating rapidly at the end of the 1890s. Thus, although the post-1900 industry expansion coincides with a take-off in domestic demand, the beginnings of blast furnace investment and production growth were coincident with relatively weak and intermittent rates of aggregate fixed capital accumulation.

The cost of capital, raw materials, and labour; intra- and intercontinental transport costs; and domestic and international demand all had the potential to affect late nineteenth- and early twentieth-century production and investment decisions among Canadian blast furnaces, but none appears to have changed in just the right way at just the right time to provide an easy explanation. A final possible factor affecting the development patterns we observe, which has consistently attracted research and policy attention in Canada, is government tariff policy.

The National Policy tariffs introduced in 1879 generated much political heat, but, as John Dales (1979) observed, there is little evidence of any substantive impact on the aggregate economy. From 1870 to 1913 the manufacturing sector’s share of GNP fluctuated between 21% and 25%, no trend being attributable to rising tariffs, and manufacturing’s share of fixed capital formation remained low. It has been argued that some Canadian prices may have been insensitive to tariff increases because the commodities in question were exported, or because import competition was suppressed by transportation costs, perishability, and/or market-specific services (Drummond 1987). Even those tariffs that raised prices need not have necessarily influenced domestic production if input supplies were inelastic, tariffs on inputs increased simultaneously, or the industry was already sufficiently profitable in the absence of trade protection (Dales 1966). However, these conditions were not ubiquitous. For some industries, including Canadian blast furnaces, the National Policy may have exerted a substantial effect on investment and production.

When the National Policy was introduced, iron importers and consumers successfully held the iron tariff to a relatively low level of $2 per ton (Canada 1881, 1882; Forster 1986), but the iron lobby gradually gained ground in successive revisions of the tariff schedule. Particularly important was a doubling of the iron tariff in 1887 to $4 per ton by the new finance minister, Charles Tupper. The rates of ad valorem effective tariff protection depicted in figure 1 and the summary statistics reported in table 1 show that during the 1880s effective tariff protection for pig iron producers rose from zero to 18%. This rate peaked at just less than 30% in 1893 before falling back slowly through the rest of our period of study.

Figure 1 also depicts the combined effect of effective tariff and effective transport protection. Effective transport protection was consistently negative throughout our period, but as intra-continental transport costs fell more rapidly than...
transatlantic costs, the net impact of transportation improvements was to increase effective protection for Canadian blast furnaces by roughly the same magnitude as the change in the value of the tariff between 1870 and its peak in 1893. In 1884, rising tariffs and bounties, the removal of duties on imported coke, and the reduction in coke and ore transport costs resulted in cumulative effective protection becoming positive for the first time. This positive effective protection was not substantial (approaching 10%) but it was persistent, and it survived tariff reductions after the Liberal election victory in 1896. Trade policy, therefore, appears quite different from the other potential influences on the investment and production patterns we observe because the more substantial changes came into effect well before 1900.

4. Providing some structure for the problem

The decision to build and operate blast furnaces in Canada during the late nineteenth and early twentieth centuries may have been related to domestic supply conditions, transport costs, international and domestic demand conditions, or the domestic policy environment. However, these determinants are neither obviously exogenous nor independent of one another. To evaluate the strength of the relationships that exist among these interdependent variables, we must introduce some statistical rigour into our effort to assess the role played by trade.
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policy in the development of the Canadian iron industry. The need for statistical rigour, in turn, requires that we first impose some structure on the problem we face.

To understand the role played by tariff protection in Canadian blast furnaces’ entry and production decisions we must consider how domestic producers responded to the complex changes that were occurring in their economic environment. Davis and Irwin (2008) investigate the role US tariffs played in fostering the early development of the US pig iron industry in a similarly complex set of circumstances. With some adaptations, we employ a reduced-form demand and supply model very similar to that used by Davis and Irwin. 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, we assume that domestic supply is a function of input \( W_K, W_M, \) and \( W_L \) and output \( P_{Cda} \) prices.\(^\text{15}\) Domestic demand is assumed to be a function of domestic \( P_{Cda} \) and foreign \( P_{For} \) output prices, tariffs \( \tau \), transport protection \( T \), and demand determinants capable of shifting the entire price-quantity schedule \( (Dom_D) \).\(^\text{16}\)

\[
\ln(Q_s) = \alpha_0 + \alpha_1 \ln(P_{Cda}) + \alpha_2 \ln(W_K) + \alpha_3 \ln(W_L) + \alpha_4 \ln(W_M) \quad (1)
\]

\[
\ln(Q_d) = \beta_0 + \beta_1 \ln(P_{Cda}) + \beta_2 \ln(P_{For}) + \beta_3 \ln(\tau + T) + \beta_4 \ln(Dom_D). \quad (2)
\]

We can derive a single, reduced-form expression, which captures all of the influences on domestic supply 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), isolating output on the left-hand side (while maintaining the assumption that \( Q_d = Q_s \) at each point in time), and including an error term.\(^\text{17}\)

---

\(^{15}\) Because raw material costs are measured in the domestic market, they include inland transport costs. We are therefore assuming a common supply response to raw material costs and inland transport costs.

\(^{16}\) Time and furnace subscripts are suppressed. Tariffs and transport costs are measured per net ton of pig iron. Foreign output prices are measured in the foreign market.

\(^{17}\) The error term in equation (3) captures measurement errors, vintage-specific but time invariant effects, furnace-specific effects, omitted determinants, and lags in output adjustment. All of these deviations from standard IID errors are addressed in our econometric exercise. Davis and Irwin (2008) multiply foreign pig iron prices by ad valorem tariff rates, thereby assuming a common demand response to foreign prices and effective protection. Davis and Irwin also include a linear time trend in their supply equation to capture technological change. We have experimented with trends. The econometric results vary in terms of significance and sign, depending on our characterization of the trend. If we include a quadratic trend, which seems to fit the data best, our qualitative conclusions are unaffected.
\[
\ln(Q) = \eta_0 + \eta_1 \ln(P_{For}) + \eta_2 \ln(\tau + T) + \eta_3 \ln(Dom_D) + \eta_4 \ln(W_K) + \eta_5 \ln(W_M) + \eta_6 \ln(W_L) + \varepsilon. \tag{3}
\]

The parameters \((\eta_0 - \eta_6)\) in this expression embody both supply and demand elasticities. For example, \(\eta_2\) captures the percentage change in equilibrium output from a 1% change in tariff and transport protection: \(\eta_2 = \alpha_1 \beta_3 / (\alpha_1 - \beta_1)\). This aggregate elasticity, therefore, depends on the elasticity of domestic supply \((\alpha_1)\), the domestic price elasticity of demand \((\beta_1)\) and the protection-induced elasticity of demand \((\beta_3)\). Parameter \(\eta_2\) will be positive if supply curves are upward sloping \((\alpha_1 > 0)\), demand curves are downward sloping \((\beta_1 < 0)\), and domestic and foreign products are substitutes \((\beta_3 > 0)\). A more structural approach would allow us to estimate each of these demand and supply elasticities separately, but decomposition is not needed because we are interested only in the producers’ aggregate responses to movements in each of the explanatory variables. This final expression – equation (3) – forms the basis of our econometric investigation, which seeks to estimate the sensitivity of Canadian pig iron supplies to international demand, effective tariff and transport protection, domestic demand, capital costs, raw material prices, and labour costs.

5. Estimating industry supply responses

We make only one change to 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 macroeconomic movements, all dependent and independent variables have been measured relative to their economy-wide, aggregate counterparts. For example, consistent with the evidence presented in table 1: pig iron output is measured relative to real GNP; foreign prices, protection, capital costs, raw material costs, and labour costs are measured relative to a wholesale price index; and domestic demand is measured relative to nominal GNP.

Our initial specification assesses the industry’s aggregate output responses (net tons of pig iron summed across all 13 blast furnaces) to changes in international demand \((P_{For})\), protection \((\tau + T)\), domestic demand \((Dom_D)\), capital costs \((W_K)\), raw material prices \((W_M)\), and labour costs \((W_L)\). In this first model foreign prices are measured as an average of US and British pig iron prices, using import shares as weights. These same weights are applied to the duties imposed on US and British imports to derive average tariff protection, and to Pittsburgh-Hamilton and UK-Hamilton pig iron transport costs to measure average transport protection. Raw material prices are measured as an average of coke and iron ore prices, using production intensities taken from US census.

18 US and British exporters faced identical Canadian tariffs until 1907, when British producers received a small preferential reduction.
reports as weights. Gross investment is used to measure domestic demand in an
effort to capture all of the sources of demand for primary iron and steel prod-
ucts, including expenditures on private and public industrial machinery, trans-
portation equipment, all forms of infrastructure, and construction and building
materials.\(^{19}\) All variables are recorded in levels for each year between 1870 and
1913.

In the first column in table 2 (OLS – Model 1) we report the parameter esti-
mates and Huber-White robust standard errors, which control for heteroscedas-
ticity and serial correlation among the regression residuals, from an ordinary least
squares estimation of our first specification.\(^{20}\) We can see that, as expected, pro-
tection and domestic demand are strongly positively related to industry output,
and raw material and capital costs\(^{21}\) are strongly negatively related to industry
output, but the connection between labour costs\(^{22}\) and pig iron production and
foreign prices and pig iron production is surprisingly weak and statistically in-
distinguishable from zero. We may interpret each of these parameter estimates as
an industry-wide elasticity. Therefore, the estimate we report for protection, for
example, indicates that on average a 1% increase in tariff and transport protec-
tion can be associated with a 1.01% increase in domestic output, holding all else
constant. Similarly, a 1% increase in raw material prices can be associated with a
2.6% reduction in output.

In this first specification we treat all imports, raw materials, and sources of
protection as perfect substitutes in the Canadian market. However, this need not
have been the case. Producers may have viewed tariff and transport protection
as imperfect substitutes because, for example, transport costs affect import and

---

\(^{19}\) Using manufacturing investment, western settlement, net migration, or railway building as a
proxy for domestic demand does not affect our qualitative conclusions.

\(^{20}\) As a sensitivity test we have run all of our industry models using first-differenced data without
affecting our qualitative conclusions regarding the connection between protection and pig iron
production.

\(^{21}\) We measure capital costs as real long-term government bond yields. This \(W_k\) does not capture
any changes in blast furnaces’ risk premia that may have resulted from the technological
transformation of the industry. Unfortunately, little capital cost information is available for
Canada and none is available for the iron industry. To test the sensitivity of our results we have
used real railroad bond yields and real government bond yields from the US, and real long-term
government bond yields from the UK in our regression equations. The sign and significance of
the capital cost and protection parameters are unaffected by our choice of \(W_k\).

\(^{22}\) We measure labour costs as blast furnaces’ share of total remuneration paid to workers in the
primary iron and steel sector, divided by hours worked in the furnaces. This \(W_L\) is dependent on
the technological transformation of the industry, which reduced the furnaces’ revenue and
employment shares. Unfortunately, there is very little wage information available for late
nineteenth- and early twentieth-century Canada, and none is available for blast furnaces. To test
the sensitivity of our results we have used US revenue and employment shares to derive an
alternative measure of \(W_L\). The sign and significance of the labour cost and protection
parameters are unaffected by our choice of \(W_L\).
TABLE 2  
Econometric results from aggregate demand-supply model

| Dependent: | OLS | IV: 2SLS | | | |
|-------------|-----|---------|----|----|
| Aggregate Q | Model 1 | Model 2 | Model 1 | Model 2 |
| Foreign P | 0.077 | -0.051 | 0.537 | (0.425) | (0.598) | (0.755) |
| US P | 0.749 | 0.356 | 0.773 | (0.983) | (0.356) |
| UK P | -0.750 | -0.773 | (0.356) | (0.357) |
| Protection | 1.010 | 1.094 | (0.448) | (0.496) |
| Tariff | 0.590 | 0.663 | (0.207) | (0.213) |
| Transport | -0.968 | -0.890 | (0.324) | (0.344) |
| Domestic D | 2.052 | 2.239 | 2.718 | (0.348) | (0.354) | (0.297) |
| L cost | -0.260 | -0.598 | -0.571 | (0.252) | (0.491) | (0.261) |
| M cost | -2.555 | -2.170 | (0.449) | (0.736) |
| Coke cost | -2.588 | -2.241 | (0.896) | (0.775) |
| Ore cost | 0.966 | 1.286 | (0.646) | (0.484) |
| K cost | -10.713 | -4.926 | -3.385 | (2.592) | (2.735) | (2.351) |
| Constant | 7.490 | 4.031 | 6.889 | (1.631) | (1.194) | (2.078) | (1.098) |
| Robust SE | √ | √ | √ | |
| Hausman | X | X | X | |
| Weak Inst. | √ | √ | √ | |
| Sargan | √ | √ | √ | |
| N | 44 | 44 | 44 | 44 |

NOTES: Robust standard errors are reported in parentheses. *, **, and *** indicate statistical significance at 90%, 95%, and 99%, respectively. 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. Foreign P, Transport, M and K costs are assumed to be exogenous. Instruments for Protection and Tariff include US pig iron duties and 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, and UK emigration. Hausman specification tests identify the presence of endogeneity. Weak instrument tests identify jointly insignificant excluded instruments. Sargan overidentication tests identify instrument exogeneity.

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

23 Tariff and transport costs are captured in our measure of raw material prices, but they are ‘buried’ in the prices, so cannot be specified independently from our protection measure.
second column of table 2 (OLS – Model 2) we report the parameter estimates (and robust standard errors) from the estimation of this second specification. We can see that US and UK imports and coke and iron ore costs did not have common effects on aggregate pig iron production. Domestic demand and capital costs still have the expected signs and they remain statistically significant. Transport costs are negatively correlated with output (and significant), indicating that input cost considerations dominated producers’ sensitivity to rail and water freight rates, while tariffs remain strongly positively correlated to domestic production. In both specifications we can identify important connections linking the output of Canadian blast furnaces to capital costs, domestic demand forces, and tariff protection.

Unfortunately, there is a potential problem that could undermine the results reported in the first two columns of table 2. The structure of equation (3) implies a particular direction of causation that may not necessarily be correct. If it is not, the parameter estimates associated with tariff protection, domestic demand, and labour costs in Models 1 and 2 would suffer from endogeneity bias. Increases in gross investment, for example, may generate demand for pig iron and induce an increase in output, but an increase in the supply of pig iron may also reduce the cost of domestically produced investment goods and induce a subsequent increase in investment. The potential endogeneity implies that our OLS parameter estimates and robust standard errors may be biased (upwards). For labour costs, our OLS results imply that lower wages may shift firms’ marginal costs downward and induce an increase in output, but increases in output may just as easily increase the demand for labour and increase wage rates, particularly in isolated regions that may be imperfectly integrated with national or international labour markets. 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 in the iron industry, 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, we must find instruments that are correlated with our potentially endogenous independent variables, but uncorrelated with our dependent variable (except through their role as an instrument).

24 The negative correlation between British import prices and Canadian production is consistent with the presence of some degree of complementarity between Canadian pig iron and British imports. The positive correlation between iron ore prices and Canadian production (Model 2) and entry (Model 4) is puzzling. This relationship may result from ore-saving technological change in newer mills, or some endogeneity in the North American ore market. Because raw material costs are not a focus of our study, we confine ourselves to the observation that these positive correlations are strongest early in our sample period, and if we use British or German ore prices, production and entry relationships have the expected negative (and significant) signs.
To address these concerns we adopt an instrumental variables (IV) estimation approach. In the first stage we use US and British domestic saving rates as excluded instruments for gross investment ($Dom_D$). Because foreign investors provided much of the capital available to late nineteenth- and early twentieth-century Canadian financial markets (Urquhart 1993, table 1.8), and because Canadian pig iron exports were near zero (implying an insensitivity to international macroeconomic and financial market conditions), these instruments capture domestic investment supply forces that are plausibly exogenous with respect to pig iron output, except through their impact on gross investment.\footnote{On average between 1870 and 1913 Canadian pig iron exports totalled 72 net tons, or 0.003\% of output, per year.}

We use US and British real unskilled wage rates, US immigration rates and population levels, and UK emigration rates and population levels as excluded instruments for labour costs in our first-stage regressions. As a result of the high degree of internal and external labour mobility during the late nineteenth century, we believe that these instruments can capture labour supply determinants and the opportunity cost of supplying labour to domestic blast furnaces – both 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 as plausibly exogenous instruments. These instruments are meant to capture forces affecting 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 parameter estimates (and robust standard errors) from the second stage of a two-stage least squares (2SLS) IV estimation strategy.\footnote{The F-statistics from the first-stage regressions for Model 1 (Model 2) are 211.6 (225.8) for gross investment, 18.0 (14.3) for labour costs, and 108.6 (278.8) for protection. Sargan over-identification tests confirm the exogeneity of the instruments in Models 1 and 2. Hausman specification tests confirm the presence of endogeneity in Model 2, but the p-value for this test is only 0.295 for Model 1. 2SLS, control function, and GLS IV approaches generate identical parameter estimates, but the standard errors vary slightly, depending on the assumptions we make about the model’s error structure.} Although the standard errors are affected, and the size of some of the parameter estimates change, in general the conclusions we can draw from the IV results are consistent with those we reached on the basis of our OLS results. In particular, protection, tariffs, and domestic demand remain strongly positively related to aggregate pig iron production, while transport costs remain quite strongly negatively related to aggregate pig iron production. Foreign prices, labour, capital, and raw material costs all have weaker and more variable connections to output, after endogeneity is controlled for. The IV estimates indicate that between 1870 and 1913 a 1\% increase in effective protection ($\tau + T$) was associated with a 1.1\% increase in pig iron production (slightly higher than the OLS estimate), while a 1\% increase in tariff protection alone ($\tau$) was associated with a 0.66\% increase in pig iron production (again, slightly higher than the OLS estimate). After instrumenting, we can see that a 1\% increase in
domestic demand was associated with as much as a 2.7% increase in pig iron production, while a 1% increase in labour costs was associated with a 0.6% reduction in pig iron production, and a 1% increase in capital costs was associated with a 9.8% to 3.4% reduction in pig iron production. The IV elasticities for $W_K$ are slightly lower than the OLS estimates, and the $Dom_D$ and $W_L$ elasticities are slightly higher than the OLS estimates.

If we step back and consider all of the results from the four econometric specifications reported in table 2, it appears that protection, tariffs and domestic demand are consistently positively correlated with increases in pig iron production, and transport costs are consistently negatively correlated with increases in pig iron production. The connections between aggregate pig iron production and foreign prices, labour costs, capital costs, and raw material costs are smaller, statistically weaker, or inconsistent across models and estimation approaches.

Of course, these elasticity estimates capture production responses to changes in the blast furnaces’ economic environment averaged over the full 1870–1913 period. Average responses do not reflect the dynamic nature of this environment. We can address this concern using aggregate production data and our reduced-form equations by allowing for differential responses before 1890, 1890 to 1900, and after 1900. If we repeat our OLS and IV estimation procedures, but introduce a linear spline with knots at 1890 and 1900 – interacted with the foreign price, protection, domestic demand, and labour cost independent variables – we find that the connections between these determinants and output vary widely over the three sub-periods. During the early period, as the regional and technological reorganization of the industry is taking hold, protection is strongly positively related to production in all specifications, but the input cost and domestic demand elasticities are relatively small and/or less significant. Between 1890 and 1899, as the new Ontario mills enter, labour costs dominate, protection is less important, and domestic demand is just beginning to exert a stronger influence. Finally, during the post-1900 period, all specifications report strongly significant domestic demand elasticities, while labour costs and protection now have lower, less significant elasticities. 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. Different forces appear to drive the industry’s production decisions at different points in time – protection matters early, labour costs matter during the 1890s, and domestic demand matters after 1900. These findings are consistent with some of the infant industry literature that argues in favour of a consequential National Policy impact (Harris and Lewis 1992).

In light of these differential sub-period effects, it seems reasonable to seek more finely detailed evidence that may help us to understand the strength and

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27 For both aggregate output and furnace-specific entry and production, the estimated elasticities from our linear spline specifications are included in the technical appendix, available from the Canadian Journal of Economics online archive (cje.economics.ca).
nature of these shifting industry output elasticities. If we had access only to 44 years of aggregate data (and hence very limited degrees of freedom), it would be difficult to conduct a more focused investigation of Canadian blast furnaces’ joint entry and production decisions during their late nineteenth- and early twentieth-century development phase. Luckily, the availability of furnace-level micro-data opens up new investigative possibilities.

6. Blast furnaces’ entry and production decisions

Our aggregate production figures may be chronologically limited, but the industry totals have been generated with information from all 13 Canadian blast furnaces operating during our period. The micro-data from individual furnaces allow us to construct a panel that dramatically increases our available degrees of freedom (572 observations in total – 232 observations with positive output) and permits a more sophisticated econometric analysis of the furnaces’ joint entry and production decisions.

Heckman’s (1979) selection model uses a two-stage maximum likelihood approach in which a probit with a [1, 0] dependent variable indicating positive output levels is run in the first stage, and a reduced-form production equation is run in the second stage. We follow Scarpetta et al. (2002) and Black and Strachan (2002) in specifying the first-stage entry equation, in which a furnace’s decision to produce or not is dependent on the expected profitability of its investment in the fixed costs of entry. The expected profitability of entry depends on not only supply and demand determinants, but the competitive structure of the market, the policy environment imposed by the government, and the cost of investment funds.

\[
Entry = \delta_0 + \delta_1 \ln(Competition_{t-1}) + \delta_2 \ln(Production) + \delta_3 \ln(Policy) \\
+ \delta_4 \ln(W_K) + \varepsilon. \tag{4}
\]

We use the number of furnaces in operation in period \( t - 1 \), 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 taken from equation (3), tariff protection reflects the entrants’ policy environment, and investment costs are assumed to be reflected in long-run government bond yields (less inflation) and the size of the investment under consideration, measured as the furnace’s market

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28 Implicit in this specification is the notion that government policy affects only contemporaneous entry decisions. We know from other capital-intensive investment projects, such as railway building (Mercer 1974), that government policy may also affect risk and the formation of expectations in a longer run, less direct way. In the absence of more furnace-specific information about investment costs and returns, this issue must remain an intriguing possibility.
share in period $t+1$.\textsuperscript{29} The second-stage production equation is again based on equation (3), and foreign prices, protection, domestic demand, labour costs, capital costs, and raw material costs are included as explanatory variables.

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 British 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 control for endogeneity with a control function approach to instrument for tariff protection, domestic demand, and labour costs, using the same instruments as we did in our industry production equations.\textsuperscript{30} For each specification we derive Huber-White robust standard errors, clustered by furnace, and we include furnace-vintage fixed effects. The furnace vintages are grouped by broadly identified technological characteristics – charcoal-burning furnaces, coke-burning furnaces, and large integrated mills. The clustering correction and the inclusion of fixed effects control for cross-furnace heteroscedasticity and serial correlation among the residuals.

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 \textit{IV Probit}), then protection is strongly positively correlated with the decision to enter the market (although the marginal impact drops when we control for potential endogeneity bias).\textsuperscript{31} Domestic demand, labour costs, the size of the investment commitment ($Market Share_{t+1}$) and the size of the competing furnaces ($Aggregate Q_{t-1}$) have the expected effect on entry, with or without instrumenting. The other measures of competition in the market, the demand

\textsuperscript{29} Manski’s (1993) ‘reflection problem’ may be a concern when we use the number of competing furnaces, total output of these furnaces, and market share as independent variables in our entry equation. Fletcher (2010, 268–71) describes how the endogeneity inherent in the reflection problem may be overcome by exploiting the time series dimension in a panel or by employing appropriate instrumental variables. We use both leads and lags of the behaviour of the furnaces’ peers to separate the competitors’ decisions in time. As a sensitivity check we use distance to primary markets, primary market size and maximum output as instruments for number of furnaces, total output and market share. Our qualitative conclusions regarding entry, production, and tariff protection are not affected by our use of instruments to overcome reflection in the entry equation.

\textsuperscript{30} The 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 thank the editor of this journal for pointing out the efficiency gains associated with a control function IV approach in the presence of non-linearities introduced by the inclusion of non-selection hazard ratios in our second-stage instrumenting equations and final-stage production equations. The advantage of the control function approach in Heckman models was first articulated by Smith and Blundell (1986).

\textsuperscript{31} The IV approaches for both stages of \textit{Models 3} and \textit{4} pass weak instrument F-tests, Hausman specification tests, and furnace-specific Sargan over-identification tests.
TABLE 3a
Econometric results from (stage 1) Heckman selection model (with furnace-level micro-data)

<table>
<thead>
<tr>
<th>Dependent:</th>
<th>Probit: ML</th>
<th></th>
<th>IV Probit: ML</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry (Q &gt; 0)</td>
<td>Model 3</td>
<td>Model 4</td>
<td>Model 3</td>
<td>Model 4</td>
</tr>
<tr>
<td># Furnaces_{t-1}</td>
<td>0.218</td>
<td>0.106</td>
<td>-1.555***</td>
<td>-1.665***</td>
</tr>
<tr>
<td>(0.387)</td>
<td>(0.451)</td>
<td>(0.611)</td>
<td>(0.733)</td>
<td></td>
</tr>
<tr>
<td>Aggregate Q_{t-1}</td>
<td>-1.148***</td>
<td>-1.574***</td>
<td>-1.200***</td>
<td>-2.290***</td>
</tr>
<tr>
<td>(0.297)</td>
<td>(0.483)</td>
<td>(0.285)</td>
<td>(0.653)</td>
<td></td>
</tr>
<tr>
<td>Average Age_{t-1}</td>
<td>-0.743</td>
<td>-0.655</td>
<td>-0.719</td>
<td>-0.743</td>
</tr>
<tr>
<td>(0.524)</td>
<td>(0.536)</td>
<td>(0.514)</td>
<td>(0.628)</td>
<td></td>
</tr>
<tr>
<td>Foreign P</td>
<td>-0.652</td>
<td>-0.757</td>
<td>0.491</td>
<td></td>
</tr>
<tr>
<td>(0.187)</td>
<td>(0.479)</td>
<td>(0.690)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US P</td>
<td>-0.282</td>
<td>0.491</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.533)</td>
<td>(0.653)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UK P</td>
<td>-0.749</td>
<td>-1.164</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.543)</td>
<td>(0.728)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protection</td>
<td>1.053***</td>
<td>0.711*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.449)</td>
<td>(0.407)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tariff</td>
<td>1.024***</td>
<td>1.557***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.362)</td>
<td>(0.562)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>-0.424*</td>
<td>-1.064***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.248)</td>
<td>(0.394)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic D</td>
<td>1.505***</td>
<td>2.620***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.517)</td>
<td>(0.626)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L Cost</td>
<td>-0.799***</td>
<td>-2.916***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.279)</td>
<td>(0.624)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M Cost</td>
<td>-0.845</td>
<td>0.585</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.746)</td>
<td>(0.744)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coke Cost</td>
<td>-2.382*</td>
<td>-3.950***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1.271)</td>
<td>(1.657)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ore Cost</td>
<td>1.809***</td>
<td>3.245***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.549)</td>
<td>(0.820)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K Cost</td>
<td>-3.705***</td>
<td>-3.789***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1.548)</td>
<td>(1.762)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Market Share_{t+1}</td>
<td>-0.986***</td>
<td>-1.020***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.168)</td>
<td>(0.193)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>1.571</td>
<td>4.206***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2.037)</td>
<td>(2.222)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Robust SE</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Cluster: Furnace</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>FE: Vintage</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hausman</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Weak Inst.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sargan</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>N_{Total}</td>
<td>546</td>
<td>546</td>
<td>546</td>
<td>546</td>
</tr>
<tr>
<td>N_{Q&gt;0}</td>
<td>219</td>
<td>219</td>
<td>219</td>
<td>219</td>
</tr>
</tbody>
</table>

NOTES: Robust standard errors are reported in parentheses. *, **, and *** indicate statistical significance at 90%, 95%, and 99%, respectively. 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 and 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, and UK emigration. Hausman specification tests identify the presence of endogeneity. Weak instrument tests identify jointly insignificant excluded instruments. Sargan over-identification tests identify instrument exogeneity (by furnace).
TABLE 3b
Econometric results from (stage 2) Heckman production model (with furnace-level micro-data)

<table>
<thead>
<tr>
<th>Dependent:</th>
<th>ML</th>
<th></th>
<th>IV: ML</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Furnace Q</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreign P</td>
<td>0.259</td>
<td>(0.622)</td>
<td>0.191</td>
<td>(0.657)</td>
</tr>
<tr>
<td>US P</td>
<td>−0.200</td>
<td>(0.248)</td>
<td>−0.313</td>
<td>(0.312)</td>
</tr>
<tr>
<td>UK P</td>
<td>−0.642</td>
<td>(1.138)</td>
<td>−0.668</td>
<td>(1.224)</td>
</tr>
<tr>
<td>Protection</td>
<td>1.400***</td>
<td>(0.632)</td>
<td>1.599*</td>
<td>(0.830)</td>
</tr>
<tr>
<td>Tariff</td>
<td>0.772**</td>
<td>(0.380)</td>
<td>0.749**</td>
<td>(0.361)</td>
</tr>
<tr>
<td>Transport</td>
<td>−0.408</td>
<td>(0.326)</td>
<td>−0.482*</td>
<td>(0.281)</td>
</tr>
<tr>
<td>Domestic D</td>
<td>0.611</td>
<td>(0.529)</td>
<td>1.075*</td>
<td>(0.531)</td>
</tr>
<tr>
<td>L Cost</td>
<td>−0.112</td>
<td>(0.476)</td>
<td>0.043</td>
<td>(0.568)</td>
</tr>
<tr>
<td>M Cost</td>
<td>−2.704***</td>
<td>(0.610)</td>
<td>−2.593***</td>
<td>(0.664)</td>
</tr>
<tr>
<td>Coke Cost</td>
<td>−0.592</td>
<td>(0.611)</td>
<td>−0.602</td>
<td>(0.630)</td>
</tr>
<tr>
<td>Ore Cost</td>
<td>−0.306</td>
<td>(0.444)</td>
<td>−0.184</td>
<td>(0.428)</td>
</tr>
<tr>
<td>K Cost</td>
<td>−4.867***</td>
<td>(1.485)</td>
<td>−2.184</td>
<td>(1.596)</td>
</tr>
<tr>
<td>Constant</td>
<td>2.047</td>
<td>(1.979)</td>
<td>1.155</td>
<td>(2.163)</td>
</tr>
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<td>Robust SE</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Cluster: Furnace</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>FE: Vintage</td>
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<td>✓</td>
<td>✓</td>
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<tr>
<td>Hausman</td>
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<td>X</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Weak Inst.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sargan</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>N Total</td>
<td>572</td>
<td>572</td>
<td>572</td>
<td>572</td>
</tr>
<tr>
<td>N Q&gt;0</td>
<td>232</td>
<td>232</td>
<td>232</td>
<td>232</td>
</tr>
</tbody>
</table>

NOTES: Robust standard errors are reported in parentheses. *, **, and *** indicate statistical significance at 90%, 95%, and 99%, respectively. 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 and 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, and UK emigration. Hausman specification tests identify the presence of endogeneity. Weak instrument tests identify jointly insignificant excluded instruments. Sargan over-identification tests identify instrument exogeneity.

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 raw material price effects (Model 4 – Probit and IV Probit), then tariffs again have a positive impact on entry, but in
contrast to the combined tariffs and transport costs in Model 3, controlling for endogeneity bias increases the impact. We can also see in Model 4 that domestic demand still has the expected effect, and transport protection has a negative impact on entry. This result reinforces our view that the effect of transport costs on input prices dominates the import protection effect.

Turning to the primary focus of our selection model exercise, in table 3b we report the parameter estimates (and robust standard errors) from the second-stage production equations. The results are reassuring and we can be brief in our assessment. A 1% increase in effective protection was associated with a 1.4% increase in furnace production levels, conditional on entry. This effect increases to 1.6% if we use US duties and US pig iron output levels as excluded instruments for Canadian protection. If we consider effective tariff protection alone, a 1% increase was associated with an average output boost of between 0.77% and 0.75%. These elasticities are statistically distinguishable from zero with at least 90% confidence, and they are slightly higher than the estimates reported in table 2 (using aggregate industry data and not controlling for entry). The point estimates on domestic demand are smaller and less significant than those reported in table 2, but for Model 4 domestic demand continues to have an identifiably positive impact on output. Raw material costs and capital costs again appear strongly negatively correlated with output levels, but the elasticities are statistically distinguishable from zero only if we consider the combined effect of coke and ore costs (Model 3). In all specifications, foreign competition, labour costs, and transport costs have relatively weak and variable effects on furnaces’ production levels.

As in the industry production equations, we again use a linear spline with knots at 1890 and 1900 – interacted with foreign prices, protection, domestic demand, and labour input costs – to allow for differential effects across three sub-periods: 1870–1889, 1890–1900, and 1901–1913. Again, the tariff’s impact on entry was largest during the first sub-period, labour costs’ impact on production was largest during the second sub-period, and the impact of domestic demand on production was largest during the third sub-period.

7. Providing some economic context

We conclude our empirical investigation by providing some economic context for the econometric results with two simple ‘back-of-the-envelope’ counterfactual exercises. Using the production equation’s parameter estimates from Model 4 – IV (table 3b), we derive annual predicted output levels for the 13 furnaces in our sample. We then calculate the reduction in production that would have resulted from the removal of all effective tariff protection. In other words, in our first experiment we ask what Canadian furnaces would have produced if the federal government had not imposed the National Policy tariffs in 1879 or the
Tupper tariffs in 1887. The results from this experiment are depicted in figure 2 (Without Cumulative \( Q \)). We can see that after 1879 production would have dropped substantially in the absence of tariff protection. On average over the full 1870–1913 period, aggregate production would have been 47.5% lower following a counterfactual removal of all trade protection, and during the last decade of the nineteenth century Canadian pig iron production would have dropped by more than 70%. Of course, if we accept the infant industry justification for protection, then the year-over-year output reductions implied by this counterfactual experiment also would have slowed the accumulation of production experience and learning-by-doing, such that there may have been even more persistent, but indirect effects on productivity and production.

In our second counterfactual experiment we re-estimate Model 4, again instrumenting for potential endogeneity bias among the tariff, domestic demand and labour cost explanatory variables. However, in this experiment we constrain our sample to include only the nine furnaces that entered during our study period (for which we can calculate cumulative output), we include lagged cumulative output (measured relative to real GNP) as an explanatory variable in the production equation, and we use a linear spline with knots in 1890 and 1900 to allow the tariff and cumulative output effects to vary across sub-periods. In this

32 This simple experiment ignores the entry and turnover that was triggered by effective protection. We are, therefore, deriving a lower bar on the output effects by forcing all furnaces, including the large, integrated mills, to enter and exit as they would have done in the presence of tariff protection.
specification, the size and statistical strength of the connection between lagged cumulative output and contemporaneous output increases sharply and the impact of tariff protection falls in each sub-period. We derive counterfactual production in the presence of cumulative output effects by iteratively removing the effect of tariff protection in each year, then recalculating 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 adjust the cumulative output effect in period \( t \) and the iterative process is repeated.

The results from this second counterfactual experiment (Including Cumulative Q and Spline) are depicted in figure 2. The impact of the tariff on production is so strong before 1890 that the removal of protection has an even larger immediate effect on output under this counterfactual. As our experiment moves forward through the sample period, the cumulative output effects grow and counterfactual reductions in output persist even after effective protection starts to decline during the early 1900s. By 1913 the counterfactual aggregate output from our second experiment is nearly 40% lower than that derived from our first experiment (which ignores cumulative output effects and does not allow differential effects across time). On average over the full 1870–1913 period, if we include cumulative output effects and allow tariff responses to change after 1890 and 1900, Canadian pig iron production would have been 63% lower, and imports would have been 109% higher in the absence of tariff protection.

There is, of course, an important caveat to keep in mind: the use of tariffs to promote industrial development is not costless. Although these experiments suggest that the imposition of the National Policy and Tupper tariffs had a substantial and potentially persistent positive impact on the size of the Canadian primary iron and steel industry, this merely implies that measurable industrial development effects offset some of the dead weight losses associated with tariff-induced price distortions for pig iron.

8. Conclusions

Much has been written about late nineteenth- and early twentieth-century industrial development, both in Canada and elsewhere in the Atlantic economy.

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33 The elasticity on cumulative output rises from \(-0.33\) in the first sub-period to 0.04 in the second sub-period and 0.42 in the final sub-period. The elasticity on tariff protection falls from 1.51 to 1.13 then 1.00.

34 Davis and Irwin (2008, 267) conclude that during the antebellum period US pig iron production would have fallen by between 30–40% in the absence of tariff protection. Irwin (2000b, table 3a) reports that in the short run the removal of US pig iron tariffs in 1869 would have increased imports by 171.7% (489.1% in the long run).

35 Following Kee, Nicita, and Olarreaga (2008) and Irwin (2010), we approximate the average annual static dead weight loss from Canadian pig iron tariffs to be 0.003% of GNP, or $24,172 per year. A more detailed discussion of this approximation is included in the technical appendix, available from the Canadian Journal of Economics online archive (cje.economics.ca).
The efficient production of pig iron on a large scale has often been used as a proxy for industrial success during this era. 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 development. In Canada the identification and assessment of the role played by tariff policy in promoting the expansion of the primary iron and steel industry is complicated by the fluid and interdependent forces acting on the domestic economic environment in the period.

We use a reduced-form demand-supply model to derive an industry production equation, which provides structure for the estimation of the sensitivity of domestic production to changes in tariff policy, while controlling for the other factors that influenced firms’ output decisions. We find that some of the forces with the potential to affect the development of the industry were in fact relatively inconsequential or of intermittent importance (international demand, capital costs, and raw material costs, for example). Labour costs declined sharply as the industry made the transition to coke-burning, integrated mills, but the development consequences of this change were largely confined to the 1890s. A reduction in transport costs modified the spatial pattern of prices, but the dramatic erosion of transport protection also turns out to have been of limited significance because of its coincident effects on import prices and raw material costs. Domestic demand, on the other hand, appears to have promoted high and rising output levels, although even this source of growth never would have had a chance to take hold if tariff protection had not begun the process of transformation. The government’s commitment to tariff protection through the 1880s and 1890s appears to have been instrumental for the technological transformation of the industry. A Heckman selection model and two back-of-the-envelope counterfactual exercises allow us to perform more narrowly focused tests of this conclusion. The evidence is consistent with the view that tariff protection was required to trigger entry and investment in larger, technologically advanced blast furnaces, and only then could increasing domestic demand be satisfied by Canadian producers.

For many years we have interpreted the National Policy’s role in the development of Canada’s primary iron and steel industry in light of the work by William Donald (1915) and John Dales (1966), both of whom argued against any substantive contribution. Our evidence suggests they are wrong. A careful appreciation of the timing of new investment, output growth, and the imposition of tariffs, combined with an explicit acknowledgment of the endogeneity of prices, government policy, and labour costs, leads to a very different conclusion – one in which tariffs really did make a difference.

References

Bell, R. (various years) *Papers and Correspondence*. Library and Archives Canada R7346–11–9-E (formerly MG 29 B15)
Canada (1881) *Debates of the House of Commons*. 24 February 1881, 1109
— (1882) *Debates of the House of Commons*. 28 April 1882, 1225
Fletcher, J.M. (2010) ‘Social interactions and smoking: evidence using multiple student cohorts, instrumental variables and school fixed effects.’ *Health Economics* 19, 466–84


— (1986b) ‘Local control, resources and the Nova Scotia steel and coal company.’ Historical Papers 21, 254–82

— (2000b) ‘Could the United States iron industry have survived free trade after the Civil War?’ Explorations in Economic History 37, 278–99


