Steel Manufacturers at the Margin in Nova Scotia

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At the end of the 1890s the Canadian economy began to expand and diversify at an unprecedented rate [64, p. 56]. Prominent among the changes was an enormous expansion of iron and steel output [19]. The largest single contribution to Canada's iron and steel "takeoff" came from a 1,000-ton-per-day plant at Sydney, Nova Scotia. This plant relied heavily upon ore from a mine located on Bell Island, Newfoundland. Because of its mediocre quality, the ore lay idle until technological change expanded the range of workable resources at the very end of the nineteenth century. Although technical progress brought steel manufacture with Newfoundland ore inside the margin of profitability, the Sydney steel plant continued to be handicapped by the poor quality of its resource base.

Iron was known to be present on Bell Island at least as early as the 1570s, during which decade ore samples were sent to England [29]. During the early 1600s detailed plans were made to mine and smelt the Bell Island ore [15, pp. 59ff]. Although smelting did not result, a mine was opened; it was still known to the residents of Bell Island two centuries later. Indeed, the mine is mentioned in a book published in 1818 and widely circulated thereafter in two editions [4, p. 66].

During the 1830s the Newfoundland legislature commissioned a geologist, J. B. Jukes, to survey the colony's mineral resources [39/I, pp. 29-30; 39/II, pp. 250-76, 320]. Jukes failed to visit the Bell Island iron mine, did not mention it in his report, and probably never learned of it. The immediate reaction to Jukes's report was mixed, although contemporaries softened their criticism by noting the immense difficulty encountered by an inexperienced geologist making the first systematic survey of a large island during two summers' field work [7, pp. 184-90].

Jukes likely would have encountered the ore except for a curious combination of circumstances. The geologist had limited time with which to survey the whole of Newfoundland. He did not stop for lengthy discussions with local inhabitants of Bell Island, and appears not to have read the book published twenty years earlier. Moreover, Bell Island, lying in Concepcion Bay, then the center of Newfoundland population and commerce [4, p. 298; 16, p. 8], was under the very noses of the geologist

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*Helpful comments on earlier versions of this paper have been received from Fred Carstensen, Avi Cohen, John Dales, and Ian Drummond. Remaining errors and weaknesses are my own.

and colonial officials. A false confidence may have been reinforced by a resemblance between the strata underlying Bell Island and those exposed on the adjacent mainland [27]. Finally, the ore was situated on the seaward end of Bell Island. This end of the island was inspected only once by Jukes late in the afternoon. Not atypical Newfoundland weather had set in: Fog impaired visibility, and a heavy sea cut short the geological inspection.

The seasick geologist overlooked or misinterpreted the visible evidence of iron; this proved to be an influential omission. Subsequent geologists and public officials used Jukes' report as the benchmark it was intended to be. When Newfoundland established a permanent geological survey on the British and Canadian model in 1864, it employed professional geologists who took their cue from Jukes. The next thirty years of publicly-financed investigation did not touch upon the Bell Island iron ore. Iron ore was sought throughout Newfoundland, and worthless deposits were discovered at several sites, but Bell Island was not re-examined closely.

The ore was not completely forgotten, however. Private merchants also took an interest in Newfoundland's mineral potential. The Bell Island mine was examined during the early 1870s and again during the late 1880s — by which time efforts were underway to sell it to British interests [8; 20, pp. 209-10, 226-27; 21]. A small Nova Scotia blast furnace company (at Londonderry), which was handicapped by the limited mainland ore deposits, also examined the mine in 1888 [37]. However, neither the British ore markets nor the Nova Scotia company took a serious interest in the ore.

The Geological Survey of Newfoundland finally learned of the Bell Island iron ore late in 1892, just as commercial interest was becoming more serious [9, p. 28]. A Newfoundlander working on a Boston street railway mentioned the ore to his employers, who happened to be in the midst of merging several Nova Scotia coal properties [20, pp. 209-10, 226-27; 48].

The Nova Scotia coal company established by the merger, Dominion Coal (DCC), was sufficiently interested to ask for an appraisal of the ore and to obtain an option in 1893 [20; 21; 48]. This led directly to the ore being smelted by the Nova Scotia Steel and Coal Company (NSSC) at Ferrona; the NSSC also began to export the ore to Germany, Britain, and the United States [36; 43]. At first the NSSC used only a small proportion of Newfoundland ore in its charge, but this gradually increased to 19 percent in 1896, 61 percent in 1900, and 100 percent for the first time in 1910 [53]. By the end of the 1890s the combination of Nova Scotia coal and Newfoundland ore was considered sufficiently reliable that a second and much larger steel company, Dominion Iron and Steel (DISC), was organized as an extension of the DCC [48]. The DCC principals had expressed an interest in smelting as early as 1893. The reason for their delay until the end of the decade has never been made clear [36], but they may have preferred to wait until the smaller steel company was able to prove the worth of the Maritime resource combination.

The preceding account confirms that the Newfoundland ore was not discovered during the late nineteenth century. The ore was not exploited for the first time during the 1890s because of a fortuitous discovery. Rather, the ore became more useful as the result of other developments. One influence that would explain why the Newfoundland ores became more valuable at the end of the nineteenth century is technical progress.

Technical change that improved the efficiency of working marginal resources is part of the explanation for the spread of industrialism from Britain to continental Europe [1, pp. 115ff; 55, p. 120]. In the case of North America, however, large reserves of iron and coal were available in the north central region to provide resources of an absolutely first-class metallurgical character at low cost [61; 62]. Early steelmaking techniques could be applied to these resources with little or no modification. This may have obscured the fact that less salutory resource combinations were present elsewhere on the continent. These peripheral producing regions of North America benefitted by the technological change as much as did continental Europe.

Two of the more celebrated metallurgical advances were the innovation of "basic" metallurgy in 1879 and the gradual reduction of production costs using the open hearth furnace for steelmaking [11; 60; 62]. The open-hearth, which began to replace the Bessemer converter during the 1880s, permitted greater quality control; this was especially useful in the working of pig iron made from resources of marginal quality.

The other metallurgical advance, the lining of steel furnaces with a basic substance, allowed pig from phosphoric ore to be used for the first time in steel production. Before the innovation of basic metallurgy all steel was produced in furnaces with acid linings. An acid lining could not remove phosphorus from the molten brew, but it did eliminate silicon at little cost. The contribution of the basic lining was its ability to eliminate phosphorus quite readily, even though it could not reduce the silicon level except at a substantial cost. Because silicon and phosphorus both had adverse effects on the quality of steel, the innovation of basic metallurgy permitted for the first time use of ores with a high phosphorus content, but it did solve the problem of ore with moderately high levels of <u>both</u> silicon and phosphorus.

By 1880, then, pig from ore with silicon and little or no phosphorus could be submitted to an acid lining. Pig iron from heavily phosphoric low-silicon ores could be converted with a basic lining. Moreover, during the 1880s, awkward resource combinations could be handled with increasing satisfaction in the open hearth furnace using one or the other of these lining. Nevertheless, certain resource combinations remained very difficult.

One difficulty concerned ores that were only moderately phosphoric. Basic metallurgy worked best with heavily phosphoric ores; in some cases the phosphorus level might be sufficiently high to be a plague on the final product, but insufficient to fire effectively the basic-lined conversion of iron to steel.[2] The Newfoundland ore happened to have a moderate level

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[2] [11, p. 174n1; 55, pp. 120-22; 58, p. 136]. Also <u>Iron Age</u>, 1/1/1885, p. 17 and 7/25/1889, p. 119; <u>Journal of the Iron and Steel Institute</u>, 59 (1901) pp. 158-163.

of phosphorus and to be somewhat silicious as well [12, p. 36; 38, pp. 129-30, 169; 41, p. 91; 54; 57, p. 47, 108]. This was a serious problem since neither basic nor acid metallurgy could eliminate easily both silicon and phosphorus.[3] Additional quality complications faced the Nova Scotia steelmakers. Although the silicon level might be reduced with heavy fluxing in the blast and steel furnaces, greater material and handling costs were incurred, and the consumption of fuel was increased.[4] The additional coke, in turn, brought with it more sulphur to the melt [5, p. 103]; indeed, the mere presence of a silicious slag induced absorption of sulphur by the metal [14]. Because Nova Scotia coals tended to be sulphurous, the introduction of additional sulphur was not easily tolerated. The less sulphurous of the Nova Scotia coals tended to have a much higher ash content and to be weaker structurally; even the strongest of the Nova Scotia coals could not support fully the weight of burden descending in a large modern blast furnace [18; 25]. Finally, both the ore and coal showed significant variations in their chemical and mechanical compositions; this was a marked nuisance in a continuous production process that worked best under strictly uniform conditions.

For all of these reasons, the manufacture of steel from Nova Scotia coal and Newfoundland iron ore was an unattractive venture until very late in the nineteenth century. By the 1890s, however, a number of minor technological advances complemented the introduction of the basic open hearth furnace in the use of awkward resource combinations. One was the principle of economical duplexing, or running the metal through two steel furnaces, one with an acid lining and one basic, in order to remove silicon and phosphorus in successive processes.[5] Another development was the tilting furnace, which eased the removal of the extra slag generated by

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[3] [11, pp. 174-77; 49, p. 26; 62, pp. 139-44]. See also Journal of the Iron and Steel Institute, 59 (1901), 507 and 61 (1902), 54-78; Journal of the US Association of Charcoal Iron Workers, 1884, 340; Iron Age, 1/1/1885, 17, 3/5/1885, 23, and 7/25/1889, 119; Iron and Coal Trades Review, (1889) 264-5, 559-60. J. Jeans, Steel (London: Spon, 1880), pp. 576, 600-06. Bell [5, p. 163] observes that "in the basic treatment an excessive amount of silicon is accompanied with considerable inconvenience."

[4] [11, pp. 174-77; 12; 58, p. 68; 59, pp. 29-42]. See also Canadian Engineer, (1895), 134; Journal of the Iron and Steel Institute, 59 (1901), 507; Journal of the US Association of Charcoal Iron Workers, (1884), 340; and Canadian Mining Review, (1898), 221.

[5] [58, p. 36; 59, p. 91]. See also Iron Age, 7/25/1875, 1 and 5/2/1902, 15-17; Stahl und Eisen, 21, 1305-13; Mining Journal, 2/7/1880, 151; Journal of the Iron and Steel Institute, (1896), 396; (1901), 474; (1902), 587; Canadian Engineer, (1900-01), 147; and (1907), 168.

the need to flux both silicon and sulphur.[6] A third advance was the pig mixer, which refined and homogenized the metal while holding it in a molten state between the blast furnace and steelworks.[7] Finally, the Nova Scotia coals could be improved by washing, which reduced sulphur and ash, and by retort coking, which increased the supportive strength of the coke [43].

All of these modifications are known to have been used by the Nova Scotia steel companies [12; 36; 43]. Together, they helped to make possible the large-scale manufacture of steel with the inferior quality of resource available in Nova Scotia. Nevertheless, steel manufacture at Sydney remained a very marginal enterprise. The persistence of a resource handicap is evident in the disparagement of Sydney's resource base by independent observers [36; 38, pp. 129-30, 169] and a candid technical account by an early DISC engineer of the many problems encountered by the steel company [12].

An examination of input productivity provides a crude test of the proposition that the resources were inferior in a way that required the use of new equipment and techniques. For example, if the above analysis is correct, iron smelting with local resources might be expected to have experienced low capital, labor and fuel productivity; conversion to steel might be expected to have had low capital and labor productivity.

Capital costs are, of course, unmeasureable. Nevertheless, the underutilization of DISC facilities in the company's early years and the company's reliance on an extensive array of ancillary equipment suggest that an unusual amount of capital probably was used. There should also be evidence of heavy fluxing, which would have reduced labor and capital productivity in addition to the direct cost of the flux itself. The data appearing in Table 1, which are calculated from reports of the Canadian steel companies to the Dominion government, confirm that the Nova Scotia furnaces did charge unusually large quantities of flux to their steel furnaces. DISC and the NSSC charged flux and pig in very different proportions than did the Lake Superior Corporation at Sault Ste. Marie, which used high-quality US resources.

The Nova Scotia blast furnaces also required much greater amounts of coke per ton of pig iron output than did their counterparts in Ontario, which used US resources (Table 2). This factor alone must have been a serious liability for the Nova Scotia blast furnaces, since coke accounted

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[6] [5, p. 113; 12; 22, p. 308; 44, pp. 71-72; 45, p. 90; 58, pp. 239-42]. See also Journal of the Iron and Steel Institute, 62 (1902), 582 and 63 (1903), 57-94; J. Jeans, American Industrial Conditions and Competition (London, 1902); Public Archives of Nova Scotia, MG 3, 1877, #45; Canada Department of Mines Report, (1908), 548. Hall [30, p. 145] observes that "tilting furnaces are more expensive to install and maintain and should not be used except where there is good reason for incurring the extra overhead and operating expenses."

[7] [55, p. 122; 58, p. 559]. See also Canadian Engineer, (1903), 140; Stahl und Eisen, 29 (1909), 1465-77; Journal of the Iron and Steel Institute, 136 (1937), 77-97; Iron Age, 6/18/1891, 1172-73.

Table 2
Coke Input Per Ton of Pig Iron Output

Year	LIC	NSSC	HSIC	DISC	LSC
1890	1.85				
1891	1.76				
1892	1.71	1.61			
1893	1.47	1.33			
1894	1.54	1.51			
1895	1.43	1.33			
1896	1.86	1.37	2.33		
1897		1.59	1.06		
1898		1.48	1.05		
1899		1.44	1.25		
1900		1.60	1.16		
1901		1.55	1.11		
1902		1.44	1.08	1.54	
1903		1.58	1.29	1.77	
1904	1.63	1.43	1.06	1.59	1.08
1905	1.58	1.27	1.04	1.42	1.04
1906	1.92	1.29	1.10	1.88	1.14
1907	2.00	1.40	1.19	1.90	1.13
1908	1.66	1.40	1.22	1.40	1.09
1909		1.50	1.11	1.38	1.05
1910		1.38	1.14	1.58	1.01
1911		1.29	1.11	1.42	1.13
1912		1.34	1.09	1.45	1.19
1913		1.42	1.04	1.68	1.15
1914		1.35	1.02	1.47	1.14
Average	1.70	1.42	1.18	1.57	1.10

LSC, DISC, and NSSC - See Table 1. LIC - Londonderry Iron Co.. HSIC - Hamilton Steel and Iron Co.

Table 1
Flux Per Ton of Pig in Steel Conversion

Year	LSC	NSSC	DISC
1910	.08	.30	.30
1911	.06	.30	.22
1912	.08	.34	.25
1913	.08	.29	.36
1914	.09	.37	.28
Average	.08	.32	.28

LSC - Lake Superior Co.
NSSC - Nova Scotia Steel and Coal Co.
DISC - Dominion Iron and Steel Co.

Source: [53]

for most of the cost of the ingot steel. The Londonderry company, which is known to have relied upon a very low-quality resource base, required remarkably large amounts of coke. The NSSC, which probably used ore with a lower silicon count on average than did DISC [36], used less coke than DISC.

The handicap borne by the Nova Scotia steelmakers also influenced the making of coke from coal. In Table 3 is indicated the quantity of coke derived from one unit of coal at each of several Canadian plants; the US average is also provided. The "coke content" of coal is one indicator of a coal's quality for metallurgical purposes. As is evident from the table, the Nova Scotia furnaces relied upon coal with a "coke content" consistently less than the US average and also less than that experienced by the Lake Superior Corporation using US coal.

Table 3
Coke Per Ton of Coal

	LSC	DISC	NSSC	Acadia	Intercolonial	US Average
1889				.53		.63
1899			.58	n.a.	n.a.	.65
1909		.68	.62	.53	.59	.66
1914	.74	.60	.52		.52	.67

LSC - Lake Superior Corporation
DISC - Dominion Iron and Steel Co.
NSSC - Nova Scotia Steel and Coal

Source: The Canadian data [53] are three-year averages centered on the dates of the US Census, which is the source of the US data. The Acadia and Intercolonial plants supplied metallurgical coke to Nova Scotia blast furnaces.

The production data indicate that technical change reduced, but did not eliminate, the resource handicap of smelting in Nova Scotia. After 1900 production in Nova Scotia remained difficult, although less so than it had been earlier. An understanding of the role of resource quality and technical progress also helps to situate the Nova Scotia steel production in relation to other questions. For example, it has been asked if the timing of overseas resource discovery and utilization during the nineteenth century was the result of chance or rational choice; discussion has focused upon the nature and importance of investor responses to <u>cyclical</u> influences [6; 50]. By contrast, the <u>secular</u> influence of technical change has been emphasized in the case of Newfoundland ore and Nova Scotia steel. The rational response by Canadian steel investors to technical change is reminiscent of the diffusion of iron production to the Continent.[8]

The story of Nova Scotia steel manufacture is also consistent with Usher's view of economically significant technical change as a succession of many discrete steps rather than a small number of great leaps forward [65]. Indeed, it is very likely that the distinct techniques identified above are only part of the story. The scientific understanding of iron in relation to the other elements improved tremendously late in the century, as did methods of instrumentation and precison control [59, p. viii]. These devlopments undoubtedly assisted the Nova Scotia steelmakers in ways imperceptible to the analyst today relying on incomplete evidence.

This Canadian industry was very much on the frontier of new technology. Hence, the example of Nova Scotia steel manufacture does not support the view that Canadian industrialization was impeded by its failure to exploit fully the available technical opportunities [10; 17; 51]. On the contrary, large-scale production in Nova Scotia was possible only because the relevant Canadian firms operated very close to the technical frontier.[9] It is true that no fundmental innovations are known to have been made during the first few years of steelmaking at Sydney. This is not surprising if, as seems plausible, metallurgical research involved substantial scale economies and perhaps also benefitted from a "learning-by-doing" effect. Nova Scotia was too remote, and its industrial community too small and as yet very new, to generate fundamental innovations before World War I. Nevertheless, steel production in Nova Scotia required an unusually sophisticated technical knowledge and the ability to adapt known techniques to the particularity of individual resource combinations. This study adds to our understanding of manufacturing development in the Canadian maritime provinces. It is now clear why iron and steel does not easily fit the pattern, identified by Acheson, of central Canadian investment in maritime industry during the early 1880s, followed by a centralization of production in central Canada during subsequent decades [2]. Large-scale steel manufacture did not appear in the Maritime region until the growth of other manufacturing industries had begun to lose its buoyancy because of the limitations of local resources and available techniques.

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[8]This technical change was not, of course, exogenous to market forces, but the market forces influencing the international evolution of steelmaking technology were international as well. The knowledge that many marginal deposits were waiting to be valorized undoubtedly directed or focused the international research and development effort, but the latter nevertheless proceeded independently of any single deposit.

[9]It is useful to distinguish two propositions. One is that Nova Scotia steelmakers possessed technical and entrepreneurial capacities enabling them to respond to the opportunities with which they were presented. A second view would assert that extraordinary technical and entrepreneurial qualities that were present constituted an independent causal influence. On the second view, the timing of the entry into integrated iron and steel production might be explained on the basis of an efflorescence of Maritime entrepreneurship about 1890. The second proposition may be implicit in some writing, but I do not advocate it.

Previous accounts of the Sydney investment explain its timing with reference to market expansion, government support, and an exogenous discovery of iron ore at Bell Island, Newfoundland during the early 1890s [19; 43; 47]. The significance of the ore discovery is that investment became more profitable during the 1890s, in part, because production costs fell with new access to inexpensive ore. Cost reductions, however, must figure in the analysis because demand and policy influences, by themselves, cannot provide a complete explanation for the timing of investment.[10]

The Newfoundland mine was the largest single tidewater source of ore in the North Atlantic during the early twentieth century. The Nova Scotia steel industry previously had been limited by a dependence on ore deposits that were small and of uneven quality [3; 19]; large-scale production in Nova Scotia would have been impossible without the Newfoundland ore.

The important analytical issue is to explain why the ore was brought into use for the first time during the 1890s. If the discovery was accidental in the sense of not being influenced by iron and steel market forces, then the traditional story would be maintained. On the other hand, if the ore came to be used because it had become more valuable, then whatever accounts for the ore's valorization would be the more fundamental influence upon investment; in this case the traditional story would be rejected. Evidence presented above indicates that the traditional story is wrong. Instead, it is argued, independent technical change made the Newfoundland ore more valuable and contributed to the decision to use it at Sydney (and elsewhere) during the late 1890s.

The delay in entering production influenced the long-run path of capital accumulation in Nova Scotia steel production. In the interval between the National Policy boom in other manufacturing sectors and the iron and steel "takeoff" about 1900, the locus of economic activity in Canada shifted markedly to the west. Hence, the delay in entering steel production reinforced the transportation cost burden of a maritime location

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[10]Macgillivry's detailed account [48] of the formation of DISC suggests the endogeneity of changes in public policy. When private investors expressed a willingness to commit resources on a large scale, the Dominion government was prepared to support them in various ways. With respect to market growth, the Canadian demand for iron products, as indicated by secondary iron production, appears to have grown very slowly during the decade preceding the investment [63]. Morerover, two large scale steel rolling plants were established in Canada at the turn of the century. If the market was large enough for two plants in 1900, then it must have been large enough for one somewhat earlier. I accept that the 1890s changes in demand and policy may have been necessary conditions for the Sydney investment, but they are not sufficient to explain its timing. It is useful to recall that the Newfoundland ore began to be used in steelmaking at the same time in a number of countries [43]; demand and policy considerations peculiar to the Canadian market do not help to explain the simultaneous beginning of Newfoundland ore export to Britain, the United States, Germany, and Canada.

and added to the problems of steelmakers already struggling to overcome the limitations of their resources and a small local market [1; 24; 42; 43].

Indeed, the metallurgical perplex may underline the "fragile structure of the new industrialism" in Nova Scotia in a more direct way [42]. By 1913, both DISC and the NSSC were encountering serious financial difficulties from which they were never able to recover fully. Part of the explanation for financial weakness may be the "serious operating difficulties" that an early DISC engineer attributes to the same resource qualities that help to explain the timing of investment [12]. The evidence on factor productivity cited above is also consistent with this line of argument. The significance of a weak resource base for steel and coal production (and the importance of both to the regional economy) is sometimes overlooked in recent analysis of regional difficulties in a "Marxist/dependency framework" [26, p. 7; 34, p. 104; 47].

The inferior quality of resource has been overlooked partly because of a systematic bias in the available sources. The steel companies were concerned to attract and maintain the support of private investors as well as public officials. A weak resource base was widely recognized to be the most serious flaw possible for a steel company — 80 percent (or more) of its costs were incurred in raw materials. As a result, anyone concerned to support the Nova Svotia steel companies was apt to ignore in public any concern about the quality of resources being used. Independent observers such as Jeans [38] or retired company officials such as Campbell [12] are more likely to provide a balanced picture than contemporaries influenced, directly or indirectly, by vested interests.

The bias could manifest itself in unexpected ways. Consider, for example, the perplexing failure of DISC to begin production on a continuous, successful basis until several years after the steel plant was erected. Campbell makes clear that this costly delay was a not unexpected consequence of the company learning to respond to its difficult technical challenge. Contemporary analysts, at least in public, told the very different story that management was incompetant. The second story had the advantage that the allegedly incompetant management could be used as a scapegoat, and replaced. The directors of the company were then able to face the capital markets with an interpretation in which previous problems could be regarded as transitory rather than persistent. No doubt the Nova Scotia steel engineers and managers made their share of mistakes, but their image as being heroically incompetent probably reflects a bias in the available sources.

Finally, it has never been clear how much of the manufacturing growth in Canada during 1900-1910 should be attributed to demand derived from the western agricultural expansion during those years [13]. However, the Sydney investment preceded the western Canadian "wheat boom." This suggests a more complex view of the Canadian economy in which several autonomous forces of growth are recognized. It is clear that the international development of new technology in transportation and agriculture influenced the timing of agricultural expansion, which in turn contributed to the extensive growth of the Canadian economy [31; 32; 40; 52]. The sources of intensive growth have been less obvious. The example of steel manufacture suggests a role for the international evolution of manufacturing technology as a source of both intensive and extensive growth in Canada before 1914.

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