The Decline and Rise of Charcoal Iron: The Case of Canada

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The use of charcoal as a fuel for iron manufacturing declined in Canada between 1870 and 1890 only to increase again between 1890 and 1913. Although this old method of iron manufacture is generally believed to have become obsolete in North America during the mid nineteenth century, it survived in Canada at the end of the nineteenth century because the price of charcoal declined and the technology of smelting improved. Charcoal iron manufacturers successfully responded to the challenge of the late nineteenth century by adapting for their own use a series of innovations pioneered by the competing technologies of coke manufacture and coke iron smelting. Before explaining the Canadian industry's successful revival after 1890, however, it is useful to consider the decline between 1870 and 1890.

The Canadian industry contracted between 1870 and 1890 because its production costs did not decrease sufficiently to offset adverse trends in the metal markets. More specifically, charcoal iron was challenged by technical improvements in the manufacture of steel and coke iron, which reduced their cost and im-

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proved their qualities. Moreover, iron foundries in the late nineteenth century for a variety of reasons learned to use coke iron in certain specialty castings which previously had required charcoal iron. The result was a decline in the cost of competing metals and in the "quality premium" that consumers were prepared to pay for charcoal iron.

In order to offset these influences, the manufacturers of charcoal iron needed to reduce their own costs. In Canada, a cost reduction was achieved during the 1890s, at which time the industry was able to attract capacity-expanding investment.

The cost reduction of the 1890s runs contrary to certain expectations. Charcoal iron manufacture in this period is generally presumed to have suffered rising costs by virtue of an increasing scarcity of charcoal and a presumed technological stagnation. In fact, after 1890 in Canada charcoal prices fell substantially, and charcoal smelting proved to be technically progressive in a variety of aspects. The technical improvements and fuel price decline substantially altered operating conditions during the 1890s.

The cost of producing charcoal iron in this period is explored by estimating a transcendental logarithmic cost function on firm-level Canadian data. The estimation leads to the conclusion that three different resource-technique combinations for producing charcoal iron coexisted in Canada during the late nineteenth century. The modern technique was characterized by a hard-driven and super-heated blast; it was introduced during the 1890s and yielded much lower unit costs at large output levels. Significant size economies are observed along the short-run cost curves of individual plants. The elasticity of demand for fuel was very small, suggesting that movements in the price of charcoal had a proportional impact on the cost of producing charcoal iron.

These characteristics of the structure of production indicate that costs were reduced by turning to a new smelting technique and to the by-product recovery production of charcoal. The modern technique of smelting with charcoal improved the productivity of fuel, labor and capital. By-product recovery kilns

"distilled" wood to yield both charcoal and certain chemicals of commercial value. The resulting charcoal was of a quality to sustain long distance transportation by rail and to support the material burden of a blast furnace producing at large levels of output. The modern charcoal kilns generated additional revenue from the sale of chemical by-products; hence the large-scale, modern blast furnace was assured an adequate supply of low-cost fuel.

These new techniques provided the cost reduction essential for the survival of charcoal iron. By-product distillation and charcoal smelting with a hot and hard blast were used in the US during the 1870s. In Canada, however, they were not introduced until the 1890s. What accounts for the slow adoption of the new techniques in Canada?

In examining the delay, I reject hypotheses based on alleged inadequacies in the Canadian supply of finance, transportation services, material resources, and public policy. To be sure, the cost and quality of available material resources help to explain the location and relocation of production within Canada. But the evidence for resource depletion is ambiguous. There is no clear evidence of rising resource prices or declining productivity in resource extraction. Moreover, American resources were accessible; they could be and were imported.

Similarly, I reject the hypothesis of inadequate transportion facilities. The relevant mineral-bearing and forested area of Canada was situated within a hundred miles of Lake Ontario; the region was well-supplied (probably over-supplied) with railway lines to the lake by 1880. If it had been necessary, additional track could have been laid at reasonable cost.

Another possible explanation for the slow move to reduce costs rests upon the suggestion that there was some difficulty with the domestic supply of manufacturing finance. The most recent version of this suggestion, which has a long historiographical tradition in Canada, springs from the wedding of a Marxist stage theory of growth and the "Canadian" staple theory.

Capital market failure is alleged to arise in the following manner. A considerable portion of the investible wealth in Canada had been accumulated in staple production and commerce; this wealth was controlled to a significant extent by domestic merchants, financiers, and the firms in which they were active. These mercantile and financial individuals and firms invested their wealth in a way that was biased against the manufacturing sector, the growth of which was hampered and warped in consequence. Foreign capital filled the gap to some extent, but this solution was imperfect for a number of reasons.

In evaluating this argument, which has been discussed widely among Canadian economic and business historians, I suggest various reasons why it is implausible. Nevertheless, the argument is an empirical proposition; it should be accepted or rejected through an examination of the relevant evidence. I consider two types of evidence, both qualitative. One is a survey of a large number of manufacturing industries located in all regions of Canada which experienced at least some mechant and/or financial involvement. In many cases the commercial/financial involvement in manufacturing was quite substantial. The second is a more detailed examination of primary and secondary iron finance in nineteenth century Canada.

To a very considerable extent the investors in various types of iron production were merchants, financiers and their firms. Few committed their resources to charcoal iron, but the reason is unlikely to have been an aversion to manufacturing investment in general or the iron industry in particular. Although it is not possible to specify precisely how many examples of cross-sectoral investment are needed to reject the argument of capital market failure, the available evidence is arguably sufficient.

Another potential influence that has attracted considerable comment is government policy. The Canadian "National Policy," which was introduced in 1879 and revised several times in the following two decades, provided a considerable measure of protection to the iron industry. It is possible that charcoal iron production late in the nineteenth century was an inefficient way to

produce iron even using the new techniques. If so, investors may have hesitated to commit their resources until the shelter afforded by the Canadian tariff had increased sufficiently.

Unfortunately, timing evidence is unlikely to be of much assistance in assessing the impact of the national policy.The market expanded and costs declined at the same time as policy became more supportive. These trends were sufficiently continuous that timing evidence cannot effectively distinguish the impact of policy. Policy changes correlated positively with new investment, but so also did the business cycle. More important, by 1900 charcoal iron in Canada was produced as cheaply as the import-competing US charcoal iron and almost as cheaply as Canadian coke iron. By 1900 Canadian charcoal iron furnaces using the new techniques do not appear to have needed protection.

Having rejected capital market failure, transportation inadequacy, resource endowment, and public policy as explanations for the decline in production between 1870 and 1890, I turn to consider more closely the characteristics of the technology with which costs eventually were reduced. Four pieces of evidence are examined. (1) The new smelting technique generally appears to have been used in a scale range very large relative to the size of the Canadian metal market. (2) Indeed, charcoal iron furnaces experienced significant scale economies operating in the scale ranges observed in Canada. (3) Not surprisingly, the number of charcoal blast furnaces in Canada was very small. (4) A single bank of by-product recovery kilns in the 1890s typically produced more charcoal than could have been absorbed in the Canadian market had blast furnaces not been active.

The following story is suggested. Before the 1890s the Canadian metal market was not large enough to allow the new technique to be used to its full advantage -- especially in the presence of several small, higher cost plants that were slow to shut down. Nevertheless, the domestic demand for metal was growing quickly. A plant built in 1898 appears to have been the first to operate at a scale that exploited fully the cost advantages of modern charcoal iron technology. Expansion during the 1890s

of charcoal smelting enormously increased the domestic demand for charcoal; this made possible a growth of by-product distillation and reduction in the price of charcoal. I conclude that the fast growth of a small metal market is the key to understanding the pattern of Canadian charcoal iron production.

In summary, the patterns of output and investment are explained partly on the basis of cost-developments and partly by demand-developments. Public policy had no effect on the former and affected the latter only insofar as it provided protection and subsidy. Other aspects of demand, however, appear able to explain the observed development of the industry. Subsidy and protection were unable to ensure the survival of older and inferior producers. Nor was the actual impact of tariffs and subsidies sufficient to have ensured the creation or survival of new plants if they had not benefited from scale economies, a favorable technology, and comparatively cheap raw materials. Alleged inadequacies in the supply of capital, transportation services, and raw materials are also found not to have been important influences.

It is worth setting the Canadian industry in its international context. Wood was plentiful and cheap in nineteenth century Canada, as it was in much of North and South America, and in northern and eastern Europe. For the most part, wood was inexpensve because forest land itself was abundant. On the other hand, coal was expensive and/or of poor quality in many of the same regions. Not surprisingly the use of charcoal fuel in iron smelting persisted much later in these regions than in Great Britain or in western Europe. It is reasonable to suppose that the international pattern of charcoal iron persistance, including the case of Canada, reflects the influence of land abundance and, hence, resource prices upon the choice of technique.

Resource endowment affected the nature of technology, as well, through industries related to charcoal iron. Between 1880 and 1920 Eastern Europe and North America supplied most of the world's methyl alcohol and acetate of lime; these hardwood distillates were produced jointly with charcoal and, in many cases, with iron. In Canada, for example, the last charcoal iron fur-

naces were operated by the Standard Iron and Chemical Company. The availability of abundant land and cheap charcoal iron also permitted the existence of certain secondary iron trades. Malleable and chilled iron foundries, for example, relied upon charcoal iron to produce machinery pieces with a unique combination of properties: intricate shape, stress-resistance, light weight and low cost. Railway vehicles and agricultural implements made extensive use of these specialty castings in the decades before small-scale steel castings became available on an inexpensive and reliable basis.

Charcoal iron smelting, specialty founding, and the manufacture of hardwood distillates survived during the late nineteenth century only in regions of abundant forest land. These industries were active in Canada and in other regions of cheap wood, but not to any significant extent in western Europe or Great Britain during the late nineteenth century. Land abundance and the ability of old technologies to borrow from the new explain this international pattern of manufacturing activity.