# Learning in Steel: Agents and Deficits

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## 1. Introduction

Alternative steelmaking technologies and the globalization of steel markets have seriously challenged the survival of the traditional leaders of the Ontario steel industry, Algoma, Dofasco, and Stelco. Starting in the 1960s with the emergence of the "minimill" electric arc furnace technology (EAF), the "big three" producers have been under pressure to replace their original Open Hearth furnaces and upgrade the basic oxygen furnaces (BOF) that are the backbone of traditional, integrated steel production. In the 1990s, the outsourcing of parts and component manufacturing by auto companies added to these competitive pressures. Unprepared to meet the challenge of automotive supply chain "system integration,"[1] traditional steel makers watched as many service centres, once distributors of steel, began to manufacture auto parts, winning the lucrative automotive steel contracts that are an important source of revenue for the integrated mills. Finally, the dramatic rise in imports of the last decade has jeopardized the well-being of BOF operations like never before, introducing cheaper steel and more steel producers into an already crowded marketplace.

A common response of integrated mills to these competitive demands has been to turn to new technology. Developments in ferrous metallurgy, automated process control, and lasers are some of the hi-tech solutions sought to produce higher quality steel in shorter production times and to break into the lucrative auto parts market. However, as they seek new economy solutions, Algoma, Dofasco, and Stelco find themselves burdened by the constraints of their old world production role, as decreasing returns combine with the highly capital intensive nature of innovation in the steel industry to limit the research and development resources necessary to make the desired transition.

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[1] Defined by Belzowski and Flynn (1995) as the shift in technical and coordination responsibilities from auto assemblers to suppliers of both basic automotive materials and parts (p.20).

In this paper, we explore the ways in which government, universities, and colleges are assisting Ontario's traditional steel companies in acquiring the technology necessary to make the transition to the new steel economy. On the basis of discussions with officials in industry and the various public institutions supporting it, we argue that government is performing a critical function in a serious private sector research and development gap. We count three overarching ways in which government and institutions of higher learning are contributing to the sustenance of Ontario's integrated steel sector:

1. University and government labs are performing forward-thinking research on improvements of current processes and new processes;
2. University departments and community colleges are working to address escalating personnel shortages in the operational side of the steel industry, providing the technical skills to implement novel processes and to perform the high-order problem solving of modern steelmaking.
3. Public institutions are fostering tacit technological knowledge transfer by creating intensive networking and associational linkages within and between sectors.

While these findings conform to Schumpeter's famous prediction that the drive for technological innovation lends itself to organizational innovation, basic research and inter-firm collaboration in the Canadian steel industry are highly dependent on *government* support, both financial and organizational. Not only are public institutions backing highly costly and risky innovative research in steel making, they are fostering teamwork among steel producers and, often, their suppliers and customers. In doing so, these agencies and research institutes are replacing functions carried out primarily by private companies as recently as ten years ago, tasks which companies can no longer perform due to the economic downturn of the industry in the 1990s.

Our discussion unfolds as follows. First, we provide an overview of the competitive forces facing the integrated companies and the learning strategies adopted by the firms to address these challenges. Then, we draw a sketch of the public institutional infrastructure that has emerged to assist the integrated mills with the hi-tech learning curve and highlight five critical functions performed by these institutions. Finally, we contemplate the question of whether Ontario's big three steel companies inhabit a "cluster." In response, we claim that the companies are embedded in a *network of learning*, rather than in a cluster. By network, we mean that the integrateds and the institutions that support them learn from each other in formal and informal associations, but that the learning that takes place is not as intense as that within a cluster due to the geographic constraints on members of the integrated steel learning network, who are scattered in various centres across Ontario and Quebec. This being said, we argue that location does matter if company leadership wishes to take advantage of its proximity to a network of researchers, and we illustrate this with the case of Dofasco's cutting-edge process control group. In short, location facilitates a positive reinforcing, stretch process: innovating companies are able to leverage local resources to accelerate the pace of the learning curve. And, in the process, through access to dedicated research capacity and people, they are able to enter new products and process improvements beyond what a passive 'turnkey' approach would have produced.

## 2. The New Steel Economy and Firm-Driven Learning Strategies

Canada's integrated steel producers have experienced a challenging period of adaptation to the new realities of the global steel market as they have had to upgrade their production facilities to respond to the dramatic growth in EAF production capacity and to deal with the parts manufacturing competence of both the EAFs and the steel service centres. The threat posed by the integrateds' domestic competitors has been compounded by the problem of cheap imports dumped on the North American market. While management recognizes that gaining a competitive advantage over domestic and foreign competitors entails investment in research and development, in-house scientific talent has actually declined in integrated steel companies in the last decade.[2] To address this learning deficit, Algoma, Dofasco, and Stelco rely to varying degrees on several of the firm-to-firm "learning channels" identified by Gertler (2001, p.10): vendor-based learning, trade,[3] joint ventures, associational alliances,[4] mergers and acquisitions, and foreign direct investment.

**Algoma Steel**

Of the three companies profiled, Algoma Steel has the most minimal active involvement in innovative learning channels. This is due to a number of factors, including its debt burden, which severely limits its availability of R&D funding. Algoma's range of learning options is also restricted by its small role in the steel-auto supply chain, the major innovation driver in the other two integrated steel companies. Unlike Dofasco and Stelco, Algoma's innovation oriented solutions focus almost exclusively on the production process rather than on expansion into downstream, value-added processing, although the company does have a division, Quality Blanks International, whose sole purpose is the sale of automotive blanks. Struggling in a market rife with cheap imports, Algoma has also opted to streamline its operations significantly, placing further constraints on the scope of its innovation-driven learning environment.[5]

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[2] Interviews: April 3, 2002 March 22, 2002a, March 22, 2002b. Exact figures not provided and are undetermined at the present time. The most dramatic example of scientific offloading by an integrated steel maker was the elimination of the Stelco Engineering unit, Steltech, the industry's traditional technical leader. But more than one interviewee commented also on the significant downsizing of technological capability of the industry's current technical innovator, Dofasco.

[3] Gertler distinguishes between "simple" and "organized" trade. We have opted to distinguish vendor-based learning as a separate phenomenon from buying and selling relationships, which we characterize as "trade." We distinguish between simple and organized trade learning strategies in our analysis where necessary.

[4] Gertler refers to "alliances," but for our purposes we have split this concept into two forms of alliances, formal and profit-driven joint ventures and informal, learning-driven industrial associations.

[5] For example, in 1998 the firm reorganized itself into business units as part of a longer-term effort to provide an enhanced focus for each major product line with the aim of providing better service to customers. (Algoma, 1998, p.2) A year later, Algoma decided to concentrate purely on the lucrative flat-rolled steel market, producing sheet and plate. (Algoma, 1999, p.1) In restricting its product focus, Algoma shut down its shape products caster, structural mill, and seamless tubular mill. (Algoma, 1999, p.1) The

Given these constraints, it is not surprising that we identify a relatively limited range of inter-firm learning media open to Algoma.

First, the company acquires knowledge about making higher quality steel through trade. The steel industry is standards-driven and putting products on the market generally depends on meeting continental (sometimes global) quality specifications, for example in new, light weight alloy steels.

Algoma's second non-institutional learning channel is found in its limited organized trade in auto parts through Quality Blanks International (QBI). Established as a separate business unit in 1997, QBI makes custom tailored blanks for automotive clients, (Algoma Steel Inc., 2000) a process that entails a degree of technical learning between Algoma and auto producers. In addition, through QBI Algoma is exposed to evolving automotive industry quality standards, such as the QS9000.[6]

Algoma's principal innovative response to its competitive position and profitability crisis has been the installation of the Direct Strip Production Complex (DSPC), a thin slab casting mill engineered by Danieli of Italy. Algoma's experience with the DSPC technology is instructive of the risks incurred in large-scale innovation in the steel industry, particularly innovation led by an offshore vendor. Faced with an old mill that was unable to produce the new grades of steel demanded by the market, Algoma decided to purchase the DSPC technology. (Interview, April 4, 2002a) The world's leading advanced thin slab casting and rolling mill, the DSPC has set new standards for surface quality, size, shape and consistency. (Algoma, 1998, p.7) In addition, the DSPC makes steel faster than the traditional BOF process, shortening the time period for making

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result is that in 2000, 81% of Algoma's sales were in sheet product, and the remaining 18% were from plate sales. (Algoma, 2000, p.19)

[6] QS 9000, or "Quality System Requirements QS-9000," is the common supplier quality standard for Chrysler Corporation, Ford Motor Company, and the General Motors Corporation. QS-9000 does not apply to all suppliers of the Big Three: it applies to suppliers of production materials, production and service parts, heat treating, painting and plating and other finishing services. American Society for Quality. (2001) "What is QS-9000?" Retrieved from <<http://qs9000.asq.org>>.

steel coil from liquid metal to 20 minutes instead of one to three days. (Interview April 4, 2002a) The significant reduction in production time also saves the company inventory and energy costs. (Interview, April 4, 2002a)

The benefits of thin slab casting have been offset by problems resulting to the purchase of the new technology. According to company and United Steelworkers of America (USWA) officials, implementing technology that it had no part in designing resulted in a significant profit-drain for Algoma. More than one interviewee told us that the company quickly learned that there is no "turnkey" innovation on this scale in the steel industry – the complex process of developing new methods of making steel requires staff engineers and operations personnel to be part of the innovation process from the outset. (Interview, April 5, 2002) Implementing the purchased technology became so difficult in aspects that Algoma engineers were forced to re-design parts of the operation in-house, for example, the complete hydraulics system. (Interview, April 10, 2002) By the time the mill was up and running, the company was hit with another productivity jamming knowledge deficit: an unprepared workforce. (Interview, April 10, 2002) Acquiring the DSPC technology was so costly, both in money and time, that some of those interviewed indicated that the company would have been better off re-engineering its original 106" mill and innovating on an incremental basis.

### Stelco Inc.

Until a decade ago, Stelco was the leading Canadian innovator in steel through its research arm, Stelco Engineering (Steltech). The engineers at Steltech built the company's mills and from this hands-on research and development expertise came a series of profit-driving innovations, including the world class "steel coil box" patented by the company and used globally in temperature and quality control in the rolling of steel coils. During Stelco's downsizing phase, Steltech was sold to the engineering consulting firm Hatch Associates Ltd,[7] where it is now Hatch Steltech Technologies, the technology transfer and marketing arm of the parent company. (www.hatchsteltech.com) Thus not unlike Algoma, Stelco responded to the new climate in steel production by streamlining its operations. In addition to abandoning its engineering shop, it withdrew from the container manufacturing market.

Lately, Stelco has focused on capital upgrades in response to market competition. While none of its capital upgrades have been as technologically dramatic as the DSPC,[8] Stelco has followed the recent industry standard of turning to "off-the-shelf" technology. While the DSPC case constitutes the most publicly visible display of the productivity costs of opting for purchased innovation, researchers in government labs and university institutes observe that the integrateds' reliance on external sources of process innovation seriously threatens their bottom-line due to the knowledge deficits created by outsourcing metallurgical and process control expertise.

In addition to its vendor-driven learning curve, Stelco has slightly more innovation potential in the learning channels open to it through its production of automotive steel. First, it benefits from user-producer learning in the development of its cold rolled, galvanized, and prepainted products for the auto market at four divisions: Lake Erie Steel, Stelco Hilton Works, and Stelwire Ltd, all located in southern Ontario, and at Stelco McMaster Ltée in Contrecoeur, Quebec.

In addition, Stelco is acquiring innovative know-how from its co-operation of Z-Line, a joint venture with Mitsubishi-owned MC Steel Operations. Through its 60% ownership of a zinc-coating line, Stelco participates in the management, operation, and marketing of the hot dipped

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[7] Steltech was sold to Hatch in 1993. Seventy per cent of Steltech's workforce moved to Hatch and the remaining thirty per cent were transferred internally to Stelco's Hilton Works plant. ("Stelco sells tech subsidiary." Hamilton Spectator. Friday, December 24, 1993, B3).

[8] For instance, other responses to increased competition at Stelco have included an $85 million upgrade to the plate mill. Steel from the hot strip mill destined for the cold mill is pickled at one of three pickle lines. (Stelco, 2001a) Stelco McMaster Ltee is a minimill located in Contrecoeur, Quebec. It makes billets, specialty bars, reinforcing bars, and merchant bars with automotive applications. It is equipped with a 130-ton, German-engineered Demag eccentric bottom tapping arc-furnace, a ladle metallurgy station, and a four-strand billet caster. (Stelco, 2001a)

galvanized and galvanneal sheets that are currently in high demand in the automotive custom panel market. (Stelco, 2001b)

Alliances with other steel companies offer another avenue of knowledge acquisition for Stelco. For instance, it is a partner in the Ultra Light Steel Auto Body initiative, a multi-million dollar project to demonstrate how to optimize the qualities of steel to produce lightweight auto structures that meet a wide range of mass, cost, performance and safety targets. (ULSAB, 2001) Other industry-based projects with which Stelco has recently been involved include the American Iron and Steel Institute's (AISI) Advanced Process Control programme, which was completed in 1998 and sponsored by fourteen member companies of the AISI. Its purpose was to develop advanced process sensors and software to maintain the competitive advantage of North American steel producers. During 1998, significant progress was achieved in the areas of microstructural engineering of hot strip mills, optical sensors and controls for improved BOF operation, and on-line measurement of mechanical properties. Stelco is also a participant in the AISI Committee on Manufacturing Technology, which has launched seventeen projects covering a variety of process, product, and environmental technologies. (Stelco, 1998, p.14)

Finally, in addition to its best practices learning opportunities, Stelco continues to innovate internally, but on a much-reduced scale. For instance, Stelco scientists have produced bake hardenable steels for dent resistance and formability. (Stelco, 2000, p.18) Researchers at the company have also worked on producing extra-strength grades of hot-rolled sheet that are used in automaking, (Stelco, 2000, p.18), and staff at Hilton Works are researching dual-phase and transformation-induced-plasticity steels that provide automotive customers with higher strength and more formable materials that allow for the creation of lighter and safer vehicles (Stelco, 2000,p.19)

**Dofasco Inc.**

By far the best example of a learning organization is Dofasco, the leading integrated steel producer in Canada. Like Algoma and Stelco, Dofasco has kept apace with basic steel production technology by acquiring EAF, continuous slab caster, and galvanizing technologies. Dofasco's leadership in the automotive steel industry, however, stems from knowledge-intensive activities that span both inter-firm learning and in-house research.

From 1990 to 2000, Dofasco invested $2 billion in investments intended to make it a knowledge-intensive, high-value added company. The cornerstone of the company's innovation initiative has been its *Solutions in Steel* strategy. (Dofasco, 1999, p.2) Conceptualized by company executives in 1995, *Solutions in Steel* is a user-producer learning strategy designed to transform Dofasco from steel producer to a producer that manufacturers high value-added steel auto parts. One of the earliest initiatives developed from the *Solutions in Steel* strategy was the 1997 "body-in-white" initiative, in which Dofasco stripped down the shell of a major automotive customer's best-selling vehicle in order to show the car manufacturer how new steel technology could reduce weight, cut costs, and strengthen overall design. (Dofasco, 2000a) The body-in-white program began a new trend that has since become an industry standard. (Dofasco, 2000a)

Dofasco's *Solutions in Steel* strategy is a master plan for user-producer learning that propels the company down several learning channels: joint ventures; acquisitions of leading-edge steel technology companies; foreign direct investment; sectoral research alliances; and in-house research.

Dofasco has expanded its operations to include three new production processes that generate cutting-edge products for the automotive sector. The first is Hamilton's DoSol Galva (DSG) facility, a state-of-the-art galvanizing line that is a joint venture of Dofasco (80%) and Sollac (20%), a division of Usinor of France. Usinor is Europe's largest producer of high-quality flat-rolled automotive steel. DSG can produce 450,000 tons/year when at capacity. DSG uses Usinor's technology in the production of exposed hot dip galvanized coatings. Dofasco is the exclusive marketer of the line's output in North America, which produces exposed galvanneal, *Extragal* (exposed galvanized), and unexposed galvanized and galvanneal. *Extragal,* a galvanized coating developed in the 1980s, is the feature product of DoSol Galva. It is a new product on the North American automotive market that is an alternative to electrogalvanized steel and has excellent friction behaviour, allowing for the easy flow of material into the die for deep drawn parts. (Dofasco, 2001a)

Dofasco's new Brazilian joint venture, Vega do Sul, is equally intended to position Dofasco for entry into the lucrative South American market, producing *Extragal* for the South American Auto Industry.[9] Dofasco's partners in the Brazilian project are Usinor (45%), Companhia Sidevurgica de Tubarao of Brazil (25%), Corporacion Gestamp of Spain (an international steel service centre and stamping operator) (10%).

In May, 2000 Dofasco significantly increased its innovative capacity by acquiring Powerlasers Inc, a manufacturer of laser welded automotive blanks and other components that held 1/6$^{th}$ of the North American market for laser blanks in 2000. (Dofasco, 2000b, p.12) GM, Toyota, Volkswagen, Chrysler, BMW, Honda, and Volvo are among the manufacturers using laser welded automotive blank and related component technology.

Dofasco has also been at the leading edge of learning about new markets through foreign direct investment. Dofasco de Mexico, a wholly owned subsidiary situated in Monterrey, will produce large diameter steel tubing for automotive hydroforming applications and meet additional steel processing needs in the Monterrey region. Upon completion, Dofasco de Mexico will be the only steel producer with processing and manufacturing facilities in Mexico capable of producing tubular products to meet the demanding specifications required for hydroforming

[9] Ownership of Vega du Sol is as follows: 45% owned by Usinor; Companhia Sidevurgica de Tubarao of Brazil owns 25%; Corporacion Gestamp of Spain (an international steel service centre and stamping operator) owns 10%.

applications. (Dofasco, 2001b) Capacity production at the Monterrey plant is projected to be 150,000 tons of steel tubing per year.

Dofasco's participation in the ULSAB project marks another learning media to which Dofasco is connected.

Finally, the in-house Innovation Group at Dofasco has been at the forefront of developing value-added products. For instance, recently it patented Zyplex, a versatile, ultra-strong, ultra-light and unique steel laminate that radically reduces the weight of conventional steel in transportation applications. (Dofasco, 2000b, pp.12, 16) Along with gaining manufacturing capacity, the Powerlasers acquisition has enhanced Dofasco's in-house research capacity. Innovations of Powerlasers' research arm include: bypass pre-trimming, which saves time and reduces waste; and laser cutting creates curved end multiple welds, which is a cost efficient process. Current research projects of Powerlasers include laser applications for patch welding, tailored tubes, laminate welding, inserted laser welded blanks, plastics welding and non-linear welding. (Dofasco, 2000b, p.17)

## Summary

An exploration of the inter-firm learning strategies of Algoma, Dofasco, and Stelco reveals as many problems as solutions to the barriers to innovation presented by their divestiture of internal scientific expertise. Although process innovation has been acquired through equipment purchases and mergers and acquisitions, the reliance on bought knowledge, often from international sources, is resulting in a serious lacuna of in-house information necessary to run production. The capital intensiveness of steelmaking and the innate complexities of innovation in the industry complicate best practices knowledge acquisition. This is particularly the case when companies learn from experts abroad, as technology is often flown in and implemented quickly with little of the sometimes crucial developmental interaction.

A related problem stemming from this reliance on for-profit consulting expertise is the hole created in "long-term" research in steel product innovation. Off-the-shelf technology meets short-term and immediate production needs, but does not provide companies with the basic scientific research from which self-sustaining industrial innovation grows. Inter-firm research alliances go part of the way in filling this niche, however the goals of consortia such as the ULSAB are to pool resources in order to meet automotive customer-driven standards, rather than to innovate in the realm of steel production *per se.*

### 3. Governments and Universities: Institutional Responses to the Steel Learning Deficit

The 1990s saw the creation of a network of federal and provincial agencies and university research institutes to address the innovation shortfall in the steel industry. Their focus was and still is primarily the integrated (BOF) steel sector. The primary Ontario government agency assisting steel innovation is Materials and Manufacturing Ontario, one of four provincial Centres of Excellence. Approximately 55% of MMO's metals budget of $1,574,383[10] goes toward steel-related research. (Interview, April 11, 2002) The steel sector benefits from the attention it receives within MMO's general mandate, which is to support innovative research through facilitating the development of partnerships between business and researchers. (MMO, 2000-2001, p.1) Other core functions of MMO are to train graduate students and transfer knowledge and technology to industry through funding industry-relevant basic scientific research at universities. (MMO, 2000-2001, p.1)

While the province of Ontario provides funding to university labs and facilitates partnerships between post-secondary institutions and industry, the federal government maintains its own research labs performing work relevant to steel production. There are two federal research laboratories that conduct research that has steel applications. First, the National Research Council's Industrial Materials Institute (IMI) in Boucherville (Quebec) is an

[10] Figure from MMO's Annual Report 2000-2001, p.5.

internationally recognized research and development centre focused on building inter-firm partnerships, knowledge transfer, technology development, and technical support to the metals and forming industry. (IMI, 2002)

The other federal laboratory generating fundamental scientific research and technical expertise for steel innovation is the Department of Natural Resources' Centre for Minerals and Energy Technology (Canmet). Like the IMI, Canmet facilitates partnerships between firms and offers technical support in areas relating to its mandate. (Canmet, 2002) Through its consulting arm, Engineering and Technological Services, it provides a range of services to metals companies.[11] In addition, Canmet's Materials Technology Laboratory conducts basic research in a variety of steel making and steel characterization activities.[12] It is interesting to note, however, that the initiative that steel-auto trade most significantly, the Canadian Lightweight Materials Research Initiative, has minimal resources dedicated to steel. Only one of the ten research projects currently under way is steel-related[13]; the majority of projects are dedicated to aluminum. Two studies focus on magnesium-based alloys, and one examines coating technologies that have inter-sectoral application potential. (CLMRI, 2002)

University research dedicated to steel production receive either combined or separate funding from federal and provincial government agencies and Dofasco and/or Stelco among the integrated mills (and on rare occasions Algoma). The two sites of university activity in steel that have a working relationship[14] with the big 3 integrated mills are the University of British Columbia and McMaster University. The University of British Columbia is home to the Centre for Metallurgical Process Engineering, established in 1985 by Professor Keith Brimacombe, the

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[11] Among the services offered to industry by Engineering and Technological Services: needs analysis; consultation; prototype development; design; manufacturing and fabrication; installation; repair; preventative maintenance; and quality control. (Canmet, 2002)

[12] The basic steel research projects ongoing at Canmet include: continuous casting and strip annealing; coasted and uncoated steel sheet development; phase transformation; precipitation in microalloyed steel; steel process development; steel product development; and industrial deformation process simulation. The laboratory also has expertise on steel casting and refining. (Canmet, 2002)

[13] The project is examining steel tube hydroforming, a technology geared to steel – auto trade.

[14] Scientists conducting research with applications to the steel industry are scattered across the country and some universities focus on non-BOF steel production.

first head of the Canadian Foundation for Innovation. The Centre has a mandate of quantitative analysis and design of metals and materials production processes. (CMPE, 2002) The Centre works with both Canadian metal producing industries and the North American steel industry. Its annual research budget is currently $2 million supporting 30-40 researchers and a large number of graduate students. (CMPE, 2002) Dofasco recently endowed an academic chair in Advanced Steel Processing at the Centre.

Dofasco and Stelco are the principal industrial partners of McMaster's Steel Research Centre (SRC). Created in 2000 under the leadership of Dofasco President & CEO John Mayberry on the suggestion of Keith Brimacombe, the SRC continues the relationship between McMaster University and the steel industry.[15] The SRC has projects on process metallurgy, process control, and galvanizing and steel product metallurgy**.** (SRC, 2002) The Centre shares its findings in these areas with all its private sector partners, which include Ipsco, Hatch Associates, the Iron Ore Company, and Australia's BHP.[16] (April 11, 2002) The SRC has funding for five years totally $6 million, including a $2 million contribution from Dofasco for a chair in Ferrous Metallurgy, $1 million from assorted corporate sponsors, and matching funds from the Ontario Research and Development Challenge Fund. In addition, Stelco has endowed a position in Steel Product Design with matching funds from the Natural Sciences and Engineering Research Council (NSERC).

The final major university-based institutional learning channel impacting the integrated steel companies is the McMaster Advanced Control Consortium (MACC). Founded in 1988, the Consortium is an industry-oriented research centre within the Department of Chemical Engineering. The Consortium consists of twenty member companies ranging across five industrial sectors: Petrochemicals and Petroleum, Chemicals, Control Technology, Consumer

[15] For instance, from 1996-2000, Dofasco and NSERC funded a chair in Process Metallurgy from 1996-2000.
[16] Broken Hill Proprietary Company Ltd., a company with operations in Australia, Africa, and Latin America. (http://www.bhpbilliton.com/bb/aboutus/companyOverview/ourProfile.jsp) [sic]

Products, and Materials Processing. (Interview March 22, 2002b) While Dofasco is the only steel company that is part of the Consortium, it has innovated several highly marketable steelmaking process control technologies in the course of its relationship with the MACC.

Viewed collectively, this network of government and university research institutions opens up five channels of learning for traditional steel producers:

1. Basic research on innovative steel processes;
2. Consultation resources for company-specific production problems;
3. Facilitation of formal and informal, firm-university learning networks;
4. Forums for discussion and agreement on industry-wide specification standards;
5. Highly qualified personnel training and recruiting.

### i. Basic Research on Innovative Steel Processes

Defined as research that has the *potential* to advance knowledge and technology,[17] basic scientific research is now the most significant contribution of public institutions to the traditional steel industry. The downsizing or elimination of in-house laboratories from the integrated mills in the early 1990s is seen as a turning point in the location and nature of steel innovation in Canada. Whereas some of the major contributions to metallurgical processing once came out of industrial research shops assigned with enhancing company profits, the general onus for making future innovations like Steltech's path breaking "coil box" has shifted to researchers at public institutions funded in part or wholly by government.

For instance, in the 2000-2001 fiscal year MMO provided enabling grants[18] to researchers working on seven separate material properties and processing projects.

[17]Basic scientific research is therefore distinct from research that has more immediate, practical application in the maintenance and implementation of extant technology and processes within plants. Interview, March 22, 2002a.
[18] MMO's Enabling Research Program "supports projects with the potential to advance knowledge and technology, and provide options for commercialization including investing in further development." (MMO, 2000-2001, p.5)

1. Rapid Manufacturing by Molten Metal Deposition (Toronto)
2. Grain Boundary Engineering for Intergranular Fracture Resistance (Toronto)
3. Improvement of Mechanical Properties of Cold Drawn High C Steel Wires Through Enhancement and Improvement of Processing Techniques (Toronto)
4. Supervisory Control of Flexible Manufacturing Systems (Toronto)
5. Rapid Manufacturing of Molten Metal Deposition (Toronto)
6. Dynamic Characterization of Transportation Materials for Advanced Applications (Queen's)
7. Improvement of Mechanical Properties of Cold Drawn High C Steel Wires Through Enhancement and Improvement of Processing Techniques (Toronto)

In addition, MMO recently united seven steel companies and two universities to form a research and development consortium on microalloyed forging steels. Under the explicit heading of a "Precompetitive Research Consortium," the companies and scientists involved are endeavouring to develop contributions to fundamental knowledge of steel grades and steelmaking processes that might have eventual applications to company operations. (MMO, 2000-2001)

The National Research Council's Project Bessemer is the most concerted, large-scale basic steel research effort by a public institution in the last decade. Project Bessemer is interesting for both its elucidation of innovation in the Canadian steel industry, but also because it constitutes Canada's involvement in a global race to develop a profitable "strip casting" technology. At its peak from 1985 - 1995, a total of 11 private or public-private strip casting research collaborations were underway across the world. (Luitens, 146, 161)

Project Bessemer was Canada's representative in the race to develop a viable "strip casting" operation. A process that produces steel or iron from the liquid metal stage, strip casting allows plants to skip the rolling and laminating stages of production. (NRC, 1996, p.18 (pdf)) The appeal of this technology is apparent in the fact that it is estimated to lower the total capital expenditure for steel production by a factor of 4 to 10. (Luitens, p.133) In anticipation of private sector interest in Bessemer technology, researchers at the IMI began in-house studies on strip casting as early as 1987. (Luitens, 144) In 1989, the IMI brought together a consortium of six companies (Algoma, Dofasco, Stelco, Ipsco, Ispat-Sidbec, and Ivaco), each contributing $1 million per year toward the development of the new forming technology. Our research suggests that the aim of the IMI initiative was not to aggressively pursue commercializable technology; rather, Project Bessemer appears to have been an exercise in due diligence, allowing companies to make informed investment decisions about future capital upgrades. (Interview, April 3, 2002; Luitens, 157) However, despite this reportedly curiosity-driven impetus, Project Bessemer became a top priority for both the research institute and the companies involved, with technical heads and chairmen of the companies involved meeting on a monthly basis. (April 3, 2002)

The Bessemer Project was discontinued upon completion of Phase I in 1998. The official explanation for its demise is the 25-fold increase in financial commitment necessary to continue to the second stage of the research, which required the construction and operation of a prototype mill at a steel plant. (April 3, 2002) Other explanations are that three of the integrated companies had already invested in thin slab casting operations and that there was no machine builder at hand for the construction of the second phase of the project. (Luitens, 145) However, a comparative analysis of the global race for marketable Bessemer technology suggests that Canadian companies stopped research efforts upon the successful 1997 production of the first saleable carbon steel by the joint venture between BHP of Australia and Japan's Ishihawajima-Harima Heavy Industries (IHI). (Luitens, 143)

The putative impact of the BHP-IHI strip casting venture on the decision to discontinue the NRC consortium suggests that the looming availability of vendor technology played a decisive role in the decision to abort the Bessemer project. While the consortium members were reported to be satisfied with the results of the IMI's basic research on strip casting, Project Bessemer sheds light on the barriers to indigenous basic research on steel production. Faced with an unprecedented profitability crisis and expanding global competition, Canadian companies find themselves forced to make decisions driven by short-term profit concerns that either prevent research from getting off the ground or strands more expensive projects. As a result, formerly global leaders in steel innovation are turning to off-the-shelf technologies to run their operations, making them followers instead of leaders in the global steel industry. Following Project

Bessemer, work conducted by the IMI in the area of steel has been on a much smaller scale and it often takes place in the context of research on processes with applications to a wide range of industries. (April 3, 2002)

### ii. Technical Consultation

A related way that government and university researchers are filling the void left by the dirth of R&D spending by firms is in the area of technical problem-solving. Companies are increasingly approaching academic and government experts to assist with challenges specific to their operations. For instance, many of the steel-related research projects funded by MMO have immediate benefits to specific firms. An example is the three-year university partnership between an MMO-sponsored researchers at McMaster and Meritor Suspension Systems Co. of Milton Ontario. The focus of the partnership was to improve ways that the company could produce high quality steel coils more consistently by minimizing the formation of surface decarburization. (MMO, 2000) Under the guidance of the McMaster researcher, the company enhanced its production system. (MMO, 2000) The relationship formed between the scientific expert and the plant engineers also generated a training benefit for Meritor.

The degree to which public institutions are moving into a consultancy relationship with the steel companies is not clear, however. It is safe to say that the majority of public-private research takes place in the form of consortia. For its part, the IMI categorically rejects one-to-one consulting opportunities and works entirely with sectoral groupings. (April 3, 2002) However, McMaster's SRC takes a blended approach between its basic research function and single consultancy opportunities, which are opportunities that do not draw upon the research done for the membership of the consortia.

### iii. Facilitating Learning Networks

Through the establishment of public-private partnerships, the public institutions supporting steel innovation in Canada now serve as forums for the generation of interactive learning channels between university researchers, government scientists, and companies. The formal learning mode emerging from this institutional nexus is the consortium. The establishment of research consortia is driven by the capital intensiveness of innovation in the steel industry – few, if any, basic research projects are funded by a sole firm. A spin-off benefit of this is the opportunity for company researchers to pool their resources, as in the Bessemer Project, CLMRI, and those conducted by the consortia-driven centres of steel innovation at McMaster. MMO has supported three steel-related consortia in recent years on micro alloys, auto spring steel, and steel coatings.[19]

A common vehicle for informal network building is the technical workshop. As part of its mandate, MMO funds this type of workshop, which is dedicated to specific aspects of production. A recent example is the Workshop on Hard Coatings, which exposed company engineers to the latest research being undertaken in university labs. The Natural Resources' funded lightweight materials research also holds technical conferences as part of its mandate.

Sometimes MMO and university institutes collaborate on organizing more elaborate workshops, such as the day long Workshop on the New Steel jointly sponsored by MMO and the McMaster Steel Research Centre. Day-long workshops such as this bring together scientists working on distinct but related aspects of steel production and manufacturing and expose company engineers to the latest innovations being developed in government and university labs. Similarly, the MACC's Dofasco Seminar Series, jointly sponsored by Dofasco and McMaster University, consists of intensive sessions covering selected themes in the areas of process control,

[19] The Auto Spring Consortium was lead by Gary Wayne at UofT to address the needs of the sub-sectoral steel auto spring cluster. The consortium dedicated to coatings developed a robotic tester that tests the strength of coatings and can be used on the shop floor. This latter innovation is important to Dofasco in producing galvanneal products.

measurement, automation, optimization and information technology. Recent topics of these seminars have included: *Applications of Computational Fluid Dynamics in Steel Processing; Overview of Advanced Automation and IT at Dofasco; Multivariate Statistical Analyses for Process Analysis, Monitoring, and Optimization Using Databases;* and *Process Sensors for the Steel Industry.* (March 22, 2002b)

There appears to be consensus among scientific and technical personnel that these informal learning mechanisms are invaluable sources of development for the integrated steel sector. However, our data suggest that there might be a divide between management and technical personnel at some companies. One government agency representative interviewed indicated that business managers do not often see the benefits of scientific networking. As a result, this interviewee suggested that government agencies have consciously stepped in to fill the gap left in the wake of industrial withdrawal from firm-driven technical forums such as CSIRA, the Canadian Steel and Iron Research Association, disbanded in 2000 due to lack of company support. (April 3, 2002)

### iv. Standard Specification Writing

A small but important role played by MMO is the writing of industrial specifications for steel products. In recent years MMO has produced two sets of standards that have been approved by the Society of Automotive Engineers (SAE). These specifications are geared to the automotive industry primarily. In preparing standards, MMO consults with its member steel and manufacturing companies. Once published under the AMS[20]-SAE, the specifications are used across North America. An example of an MMO generated specification is the standard for "Gas nitriding and heat treatment of low-alloy steel parts" issued in April 1987 and revised more recently.[21] (MMO, September 2001)

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[20] Aerospace Materials Specifications. See SAE, 2002.

**v. Highly Qualified Personnel Attraction and Retention**

The recruiting and training of highly skilled talent to the industry is one of the most crucial functions of the publicly supported institutional framework supporting Ontario's steel economy. Interviewees in companies, unions, government, and university labs commented on the current skills shortage of both engineers and technicians – a situation that will worsen in the next five years as the many highly trained personnel retire from the industry.

The large steel companies are turning to government and institutions of higher learning to help combat this problem. According to staff at McMaster's SRC, a major objective of Dofasco in funding the institute was to increase its visibility and access to a future stream of personnel in the school of engineering. It is estimated that 1/3 of McMaster graduates in mechanical engineering work in the steel industry, translating into 8-10 new hires per year, a rate of employment that fails to meet the needs of steel companies. There is evidence that the closeness of company – university relationships is helping to close this gap. For instance, 30% of Dofasco's highly successful Process Control Group graduated from the MACC.

By far the organization most active in addressing the skills shortage faced by the integrated steel mills is the Canadian Steel Employment and Trade Congress (CSTEC). A joint venture of Canada's steel producers and the United Steelworkers of America (USWA), CSTEC was created in the early 1990s to provide a range of human resources functions to the industry, including training services, entry-level services that assist in recruiting individuals, and worker adjustment services that assist laid off employees. (CSTEC, 2002, p.1) To fulfill these objectives, CSTEC has developed an industry-specific curriculum of general industrial courses and courses specific to the steel industry. Over 35 workplaces have used the CSTEC training program. (CSTEC, 2002, p.11)

In terms of its recruiting function, CSTEC has assisted the industry in hiring 300 young people into technician, technologist, engineering, and information technology positions through

Human Resources Development Canada's (HRDC) Youth Science and Technology Program. (CSTEC, 2002, p.11) The organization is also developing an accelerated technical apprenticeship program to replace retiring steel industry trades people more quickly than the standard 5-year apprenticeship period currently in place. (CSTEC, 2002, p.5)

According to CSTEC, the federal government is taking the lead in governmental support of worker recruitment and training programs. The Ontario government has offered no support to the organization, although a major obstacle in recruiting people to the mill floor is the provincial government's apprenticeship program policy. (April 12, 2002)

#### 4. Do Institutions Matter?

An overview of inter-firm and institutional strategies in responding to the new steel economy and to the crisis in the industry illustrates the pivotal role of governments and universities in supporting this vital, industry. At a basic level, governments and universities are assuming roles once performed by steel companies themselves. While Algoma and Stelco have focused on the short-term in light of their financial difficulties, few would quibble with the fact that the steel industry must reside in an innovative environment if it is to survive in contemporary conditions. Although Dofasco is recognized as the Canadian leader in steel product, process, and manufacturing innovation, industry observers tell us that the company lacks both the number of researchers and the R&D budget to make meaningful contributions to innovation in steel on its own. (April 3, 2002; March 22, 2002a) As such, governments and universities are stepping into a fundamental scientific exploration role once undertaken by the firms' own scientists and engineers.

While we have outlined the short-term spin-offs of maintaining indigenous scientific expertise, it remains to be seen whether government involvement will provide the support necessary to sustain the Canadian integrated steel sector, let alone to move Canada back into a leadership role in steel innovation. Several industry players have expressed the view that the takeover of Canadian companies is being driven by the knowledge-gap within firms. One executive is reported to have said that the knowledge deficit is going to result in the foreign mergers of most Canadian steel firms, leaving only five or six competitors in an industry that was once the industrial backbone of the country. (March 22, 2002a)

Whether there is the will or the capacity of government to salvage Canadian steel remains to be seen. However, a glance to the European steel – government relationship reveals that public institutions there have made a major difference in the success of some of the continent's most profitable companies. For instance, Dofasco's partner, Usinor, has a trans-continental research staff of 1,200 backed by subsidies from the European Union. (Usinor, 2002) One Canadian insider depicted Usinor as a European 'national champion' and argued that its global leadership in steel innovation is a direct result of European spending. (Interview, March 22, 2002a)

## 5. Does Location Matter?

Location and local resources matter in the process of innovation in the steel industry. How much and how it matters varies. At one end of the spectrum we have identified is the cluster-driven, in depth synergies between Dofasco and researchers at McMaster University. At the lower end of the technical spectrum is Algoma, a company that is far removed from the Hamilton cluster. Despite Algoma's location outside the Hamilton cluster, however, one can see positive examples of technological innovation spurring that company forward, such as the railway coil car and the contract manufacturing of components for GM London shared between Algoma and a limited number of machining shops in Sault Ste. Marie.

In addition, although location is important in generating tacit learning relationships, it is also crucial in the supply of skilled labour. Our research uncovered the extent to which the traditional steel producers are turning to universities, community colleges, and local workforces for a flow of workers. (Interview, April 4, 2002a) In the Algoma case, where most CSTEC training had been for workers exiting the industry, a significant number of employees have returned to the firm to work in higher level positions upon completion of CSTEC and other external sources of training. (Interview, April 10, 2002)

However, we have also learned that location matters most in steel innovation when companies are willing and able to take advantage of their proximity to neighbouring institutions. The story of Dofasco's Processing Control Groups speaks to this point. In 1991, McMaster University chemical engineer John McGregor approached Dofasco and Stelco about the potential benefits of his research in process control automation, research involving various computerized methods of assessing the quality of industrial products. Dofasco's John Mayberry was keen to join the MACC. Stelco decided not to back this area of research. A decade later, Dofasco has a 12-person process control technology group that it hopes to spin-off into a technology company producing process control technology specifically for steel applications. In addition, the company has used process control automation on 25-30 major projects across the company, bringing it multi-million dollar savings. As the first company to patent process control innovation tailored to the steel sector, the company has become a world leader in process control automation and is setting North American standards in quality control through its relationship with Ford of Detroit, which demands that all its suppliers employ Dofasco's quality assurance methods. (March 22, 2002b)

## 6. Steel Themes Arising from Interviews

A number themes warranting further investigation have arisen form our research to date. These themes will be developed in future discussions.

### 'NAFTA' Steel Industry

Particularly since the announcement of the steel trade cases, it is possible to say that the steel industry in Canada has migrated from a national industry to a NAFTA industry. On the development side, this has meant going to the 'American' model of depending on vendor-led technology development. The traditional model has more indigenous technology development. The latter started to shift with the sell-off of Steel Engineering/Steltech to Hatch Associates Ltd. Further evidence of an emerging NAFTA industry is the involvement of Dofasco and Stelco in the American dominated ULSAB initiative. Particularly, further research will attempt to uncover whether the participation of big integrateds in this continental research consortia influenced the decision to dedicate one of ten projects to steel in CLMRI, the Canadian analog of the ULSAB.

### Global 'Clusters'?

The message from researchers at McMaster was clear: new technology development in the international steel industry is coalescing around two poles: the European Usinor pole and the Japanese Nippon pole. These international poles of innovation are touching Canadian steel significantly. Dofasco relies heavily on Usinor for the acquisition of new materials, forming, and coating technologies, whereas Stelco is reliant on Nippon vendor-led innovation and consulting expertise. If the US trade cases succeed in consolidating the American industry, then there may be a US-led North American development pole in the future.

### Algoma Steel

Algoma may be the odd-man out of future developments. The DSPC is undoubtedly the most biggest single technical innovation in the Canadian steel industry since the EAF was introduced in the 1960s. It was also positioned specifically to assist Algoma consolidate a position in the auto, flat-rolled products market segment. Downstream development with the blanking operations seems like the next logical step. Many people view its locational disadvantage as too much to overcome. However, the new Ipsco processing facility in Concord, 1500 miles from its mill, belies the location-transportation factor as enough in itself. Further, the next step in development of the DSPC technology is explicitly designed to give Algoma a competitive advantage over the minimills in certain grades of steel. They may have over-invested in the one bet on the DSPC and neglected maintenance and incremental improvement in the rest of the mill and business.

It is also the case that Algoma has used more CSTEC training than any other steel plant after Algoma. As suggested above, perhaps Algoma's local cluster effort is on the skills/human resources side and less on the deep engineering side as at Dofasco-McMaster.

### Virtuous Circle/ Vicious Circle

The linkage between "innovation – profits - capital investment – innovation" can take on a virtuous or a vicious character. A strong commitment to innovate, backed up with strong re-investment in new technology, leads to more profit that further enables more innovation that leads to more profit, etc. Conversely, a lesser commitment to innovation, lower investment in new technology, leads to lower long range profitability, poorer productivity, greater downward pressure on prices, leading to lower profits and then even lower investment, less innovation, etc.

Dofasco seems to be on the virtuous cycle and Stelco/Algoma on the vicious cycle. The companies appear to have set down these divergent paths in the early 1990s, with Dofasco seeking out innovative avenues of development and Stelco getting out of the aggressive pursuit of hi-tech solutions to their declining profits. Algoma positioned itself somewhere in between its competitors by pursuing the DSPC project. The different rates of profitability and capital re-investment from 1998 onwards suggest that less than a decade after making crucial decisions about the future of their companies, the decision not to invest heavily in multifaceted technological innovation is having a serious impact on the integrated mills. In this respect, however, the 1998 Asian crisis may have been a "tipping point" for the steel industry: the 50%

depreciation of the won positioned the Korean steel producers as determinative of global spot prices in flat-rolled steel and therefore the profitability of integrated producers.

### Maksteel

Maksteel was the leading 1990s example of a traditional steel service centre becoming a contractor manufacturer for the auto industry. It seemed to be doing everything right in making a major change in their traditional business model and going into further value-added processing with a direct play to the auto industry. They started an auto division and moved into being a virtual parts manufacturer. They built a $300 million business and peeked in 2000 with a total of 500,000 tons of product to the auto industry alone. In 2001 the business crashed and two months ago it was bought by Canadian Welded Tube. Mak has now resumed business under the new owners.

The technical literature identifies supply chain surges as a chronic problem with tightly coupled auto-steel supply chains. The surges most de-stabilize the third tier supplies (steel service centres). Is this the story on Maksteel?

### Networks, Not Clusters

Our current impression is that Canadian steel innovation takes place in networks of learning rather than clusters of learning. By network, we mean learning through formal and informal associations and relationships that are less intense than relationships found in clusters. Whereas in a cluster, weekly if not daily contact can emerge between institutional and industrial actors, in a network contact is more organized and occasional, with workshops and consortia meetings forming the formal basis of communication between the actors.

### Pathways and Poles of Technological Development

If Canada has an endogenous path of firm-based technological innovation in steel, it is dominated by Dofasco. Since the demise of Stelco's engineering wing, Dofasco has been the leader in technological innovation in Canadian steel. Stelco and Algoma have resorted to vendor-led innovation, while Dofasco has played a role in the R&D process. However, we are yet to know the extent to which Dofasco innovates internally. Much of its Solutions in Steel initiative, for example, is the result of vendor-led or partnership acquired innovation.

### Innovation in Capital Intensive Industries

The steel industry case is indicative of particular problems faced by innovators in capital intense industries. The risks of innovating appear to be much greater than with less capital intense sectors. In the case of steel, an entire company can be put at risk over one project. Financial institutions may also hinder innovation by insisting on "turnkey" solutions that assume quick payback periods. Our research indicates, however, that companies take serious risks by short cutting a learning curve that is inherently cumulative. The benefits of home-grown innovation highlighted in the Algoma DSPC example reinforce the thesis that tacit knowledge depends on close contact between players at all stages of the industrial process. Ultimately, location matters and it might be particularly relevant in capital intense industries.

## 7. Conclusion

Our overview of the firm-to-firm and private-public mechanisms of adaptation to the new economy illustrates the importance of government in fostering Canadian grown expertise and innovation in Ontario's integrated steel sector. While these companies are turning increasingly to offshore partners and sellers of innovation for hi-tech upgrades, our discussion reveals that relying solely on imported innovation hinders the profitability of the integrateds in some cases. In addition, we have shown that companies can profit enormously from working with government and university researchers, as evinced in the case of Dofasco's Control Group.

While government, universities, and colleges are playing a crucial role in buoying innovation in integrated steelmaking, they are doing so largely outside the cluster model. A preliminary conclusion we draw from this is that clusters might not be vehicles of development well suited to traditional industries reliant on natural resources. While integrated steelmaking has benefited from clusters, both in terms of the Hamilton McMaster-Dofasco relationship and the hi-tech cluster in Waterloo, for instance, it cannot be said that it inhabits a cluster itself. It remains to be seen whether the absence of an integrated steel cluster will deter profitability in a future increasingly reliant on this model of innovation and production.

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