Biotech in Lunch Buckets: The Curious Knowledge Networks of Steeltown

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Abstract

The paper reports the results of the study of knowledge networks and innovation in Hamilton Ontario, Canada's classic Steel City. Contrary to expectations that there would be a Jacobean effect of accumulation of dense, interactive networks of creative resources in the city core, interview results suggest instead a Tim Horton's effect. The arts and cultural industries concentrate downtown. The overwhelming number of innovative firms prefer the weak links of suburban Flamborough and interaction through local gathering places and trade conference attendance. In addition, as an object of study and policy development, there are no longer steel companies or a steel industry in Hamilton that would be understood by any traditional resident. They have been deconstructed into global supply chains and knowledge networks.

Introduction

Background

For many observers, Hamilton is 'the' industrial city in Canada. For the past century it's steel industry and manufacturing firms made it the backbone of Industrial Canada. However in the past 20 years there has been significant diversification of the economy into other economic sectors led by healthcare and health sciences. Yet Hamilton continues to have a much higher level of employment in industrial establishments than other cities in the current ISRN study. In another dimension, Hamilton has more than twice the number of engineers as does Waterloo, but the latter gets all the points as the leading technology centre in the country.

Methodology

Theme 1 of the current ISRN study on Creative Cities focuses on knowledge networks and interaction within and between clusters and industries and with non-local actors.

In Hamilton, the approach has been to study three sectors: the steel/advanced manufacturing cluster, the health sciences cluster and the arts and culture sector. Some 55 interviews have been completed.

The central hypothesis for this Theme of the project is that the economic and creative performance of city-regions depends on three key characteristics: the strength of local knowledge flows within individual industrial sectors, the strength of local knowledge flows across industrial sectors, and the strength of knowledge-based linkages between local and non-local economic actors. The working hypothesis is that: the economic performance of city-regions depends on the density of local networks, the relative mix of local and non-local ties, as well as the heterogeneity and diversity of economic actors belonging to these networks.

The primary question we were asked to address is: Based on the research from the case study, to what extent do the strength of knowledge flows affect the nature of the innovation process in Hamilton, and how has knowledge circulation influenced the economic development/trajectory of the city?

Pre-Suppositions

The academic literature has defined actors in knowledge networks in two categories:

> Communities of Practice typically made up of engineers who interact with peer-to-peer exchange about largely tacit knowledge of how things work;
>
> And, Epistemic Communities of scientists who primarily exchange codified knowledge through academic publishing, academic conferences and patents.

Hamilton initially appeared as almost a laboratory controlled study of this topology. The steel industry's technological development for a century was led by the National Open Hearth Conference and its successors. This was a gathering of metallurgical engineers who regularly gathered to exchange their experiences and practices. Across town, the establishment of the McMaster University Medical Centre and subsequent incorporation of Hamilton Health Sciences concentrated a huge number of medicine and bio-medical researchers in one network

of hospitals, clinical and research centres. Hamilton seemed to fit the practice-epistemic topology in textbook-like fashion.

However, the interview results have taken us in a completely different direction. The conclusion of our study is that what we have in Hamilton are two synthetic knowledge networks operating in tandem and occasionally with somewhat unanticipated synergies at both the formal governance level and at the startup company funding level.

Research Findings in the Theme 1 Hamilton Case

Agglomeration Economics: Jacobean Effect

Contrary to expectations that there would be a Jacobean effect of accumulation of dense, interactive networks of creative resources in the city core, interview results suggest instead a Tim Horton's effect. The arts and cultural industries concentrate downtown. The overwhelming number of innovative firms prefer the weak links of suburban Flamborough and interaction through local gathering places and trade conference attendance.

One interesting divide between different interviewees was that some seemed more urban and others more suburban. The former typically worked and lived downtown felt strong passion for the city of Hamilton (and occasionally had negative feelings for places like Burlington). They enjoyed having shops and services nearby and appreciated the burgeoning arts, culture and sports. This was particularly true of those in the Arts community, as well as some in the health-science field located close to McMaster.

The majority of private sector managers interviewed however, and the majority of successful businesses, were located in suburban areas such as Ancaster, Burlington and Flamborough. From a residential standpoint, these individuals enjoyed quiet and friendly neighbourhoods in the suburbs or the country, which were a short, quick drive from their job. They also found that suburban business parks were able to provide the reasonably priced land and services that their organizations required.

The urban/suburban divide seemed to manifest itself in other ways too. Suburbanites tended to have stronger international networks, and less connection to the immediate area around their business. Urbanites by contrast seemed more embedded in their local community and more likely to cross-pollinate with other locals, including those from outside their industry.

The success of the suburban areas may point to a trend in which economic growth in the city of Hamilton will go from the outside-in, with success in the suburban regions generating greater investment in the urban core - as opposed to the traditional model of major industries and

population in the core radiating outwards. This core may still be characterized by growing artistic and service based industries but they may be the import substitution spin-offs of the successful suburbs rather than the source of the city's revitalization.

Some managers were directly critical of city politicians and planners trying to force feed Jacobean development downtown and neglecting housing needs closer to the new Industrial Park.

> They want everybody who works here to live downtown, so there's no residential planning in the area. Rather than putting up 15 acres of the 139 into high rise condos – people live and work in one area – but no, someone on city council says 'we have to develop the downtown core to attract people down there, so that's where the residential should go.[1]

A heretical challenge to the current Gods of planning and space utilization!

Boundary issues also presented at the circumference. Emerging industrial sectors in Hamilton are not easy to identify and when interviewed, the respondents are not clearly linked to each other through established community linkages e.g. Chamber of Commerce, MMRI. There is also a gap between data sources. The CMA data include Burlington and a significant ICT sector that is not evident in the traditional City of Hamilton. The Hamilton Spectator recently featured a profile of a 400 person software and switching company, Evertz Engineering in Burlington, which is rapidly growing in a niche space facilitating HD video streaming.

As well, steel cluster developments such as Hatch Engineering are clear if one looks as far as Oakville, but not within Hamilton itself. This may be an indicator that the Hamilton materials/manufacturing sectors have become more a part of the GTA economy than that of the old municipal boundaries. Other such outward oriented initiatives include the Golden Horseshoe Biosciences Network and the Golden Horseshoe Manufacturing Network.

For Steel Town, a larger policy issue here may be relate to the controversy about the 'hollowing out' of manufacturing. In the case of steel, it may be more a case of blowing out than hollowing out – where the top five producers have all been taken over by foreign companies seeking to

[1] Confidential interview, technology incubator manager, Oct 16, 2006

penetrate or consolidate their positions in the North American steel market. For the local city-region, in manufacturing with mergers into global supply chains, it may be the case that you gain more in managerial talent and access to technology than you lose in control. And, with smaller negative effects on related services and suppliers. Recent studies of Pittsburgh (Treado 2008), validate a different trend than the shift from steel to health sciences in Pittsburgh, that has recently caught public attention in Hamilton (Hamilton Spectator March 7, 2009). Treado traces the expansion of the Steel Technology Cluster in Pittsburgh. In the period during which Pittsburgh lost all of its city-sited steel mills, the cluster has grown to the point where it employs more total people and at higher wages than the steel industry of Pittsburgh did in its prime. There are suggestions in the interviews of similar dynamics in Hamilton.

> Some of the smaller high tech equipment suppliers, some of whom are local and some who are international. For example, we'll have an idea of how to change a control system, we'll give it to them and they'll ratchet it up and we'll ratchet it up and then we've gone something that's better than anyone else's – that's very common. We have all kinds of partnerships with suppliers to create unique equipment. For example, when you roll steel, the rolls can get very hot or the metal can crack or explode so you have to test them with sensors for internal stresses and we've done that with outside companies and obtained patents, or we get the patent and sell it or license it to them.[2]

By contrast, in other cities, such as Toronto, it may be different for financial services. Banks and other financial services companies may be much more critical to co-location of legal and accounting talent than manufacturing sectors. This may be the contrast between Toronto financial services for instance and Halifax.

The Strength of Local Knowledge Flows Within Industrial Sectors

A strong manufacturing cluster remains in Hamilton. To some degree, this is the result of the city's history, rather than its present. Many organizations identified a large pool of experienced individuals in all categories, including engineering, management and unskilled labour. In some ways, the recent upheavals in the industry have been a benefit.

[2] Confidential Interview, former Dofasco executive, Oct. 16, 2006

Several interviewees noted that there are few better economic locations for any company than the Golden Horseshoe. Hamilton maintains a high concentration of manufacturing and steel companies and assets that serve as suppliers, customers, partners and service people. Despite the downsizing of their operation Stelco and Dofasco remain vital customers for organizations like engineering firms and steel processors.

Steel Knowledge Network Actors

The steel industry and its related user-industries has been the dominant industrial presence in Hamilton, the country's leading industrial city. Consequently, the history and stages of development of the steel industry has dramatically effected the local/non-local focus and linkages of the steel industry, its firms and suppliers.

Steel 1: The Stelco Era

City-regions are critically impacted by the trajectory of their anchor firms. The Steel Company of Canada (Stelco) has held a much more dominant place in Canadian industrial history than even the legendary US Steel dominance of the American steel industry. The era of the strongest local linkage was the classic period from about 1905 to 1985 led by Stelco, with its indigenous technological leadership of the Canadian steel industry's development, rhapsodized by William Kilbourn's 1960 history of Stelco as the material expression of the Empire of the St. Lawrence.

> The Steel Company of Canada takes the very shape of the Great Lakes and their River. From Newfoundland to the Minnesota shore of Lake Superior it has grown by the inland waters, as if it drew its lifeblood from the great artery of the continent. Down lake and river to the east of these Heights lie the steel-finishing plants at the Humber's mouth, Toronto, at Gananoque in the Thousand Islands, along Montreal's Lachine Canal, and at Contrecoeur several miles farther down stream. Another is planted due west of here in the Grand River city of Brantford, just South of the first terminus of Governor Simcoe's road from the head of the lake. Another is on the Welland Canal. Three more, scarcely visible, are tucked at points seven miles apart in indentations of the Hamilton shore line. From the Mesabi range at the head of Lake Superior comes the Company's iron ore, though one day even richer holdings north of Seven Islands on the lower St. Lawrence will furnish the chief source of supply. Coking coal is mined from the Allegheny slopes in Pennsylvania, directly to the south. On Lake Erie at Beachville, Ontario are the limestone quarries that provide iron's third ingredient. All along the same Empire of the St. Lawrence lie the major steel-using markets of industrial Canada, whose lifeline, like the company itself, has been so powerfully shaped by the folds of rock and soil and water of central North America.

Kilbourn, **The Elements Combined** (1960)

Stelco's economic footprint was not just a historico-literary metaphor. Its 1200 engineers in Stelco Engineering was the largest concentration of engineers, outside of Ontario Hydro, than of any company in Canada. It was also the pioneer among North American steel companies in the 1930s in sending out its metallurgical engineers to work in the plants of its manufacturing customers to educate and do application development (Kilbourn 1960).

Any pedestrian walking down the street in Hamilton in the past century knew what the steel industry was and who the players were: There were two gigantic steel companies – Stelco and Dofasco – each with huge integrated steel mills within the city limits. Hamilton and area had over 60% of the steel capacity for the whole country. However at the formal governance level there were culture wars between the two companies. The clash was between the unionized, traditional industry leader – Stelco; and, the non-unionized, rising Dofasco. In the 1990s Dofasco would displace Stelco as the industry leader. These differences at the top, among other things meant that there was no clear Canadian industry voice. Canada's major steel producers were all members of the American Iron and Steel Institute (AISI). It was only when the American industry went protectionist under the Reagan steel programme in the early 1980s that the Canadian companies formed the Canadian Steel Producers Association (CSPA) in 1986.

On the ground, however, the reality was more complex. Groups of steel engineers from both companies, for instance those dealing with blast furnace issues, would meet regularly. They also both participated in industry association technical committee. Historically this meant the National Open Hearth Committee and later as associational governance evolved: the technical committees of the American Iron and Steel Institute (AISI), International Iron and Steel Institute (IISI) and CSPA. Again, these remained largely committees of engineers talking to other engineers.

Hamilton's dense concentration of engineers, of all specialties still remains. To today, Hamilton ahs over twice the number of engineers than does Waterloo. However, from the media to policy makers, Waterloo remains Canada's poster place for engineering and technological excellence.

The Engineering labour market has had less attention, perhaps because it has been dwarfed by the profile and impact of the industrial labour market, particularly the unionized sector.

Labour market regulation was also much more a mixed message than the union/non-union distinction at the top. Dofasco invariably followed the wage and benefit patterns, with a time lag, that were negotiated by its neighbor with the United Steelworkers union (USWA). More interestingly, where work organization and work rules have come to be seen as more critically important than just official wage levels, the Co-operative Wage Study (CWS) job classification of the USWA which codified every skill cluster/job description in the whole steel industry into one hierarchy, was itself also implemented, as the industry standard, into Dofasco as well as Stelco. This union-led system, which for many observers represented the quintessential work rule rigidity, was administered in both plants, including the poster non-union employer! To complete the picture, when the industry crisis of the 1980s led to establishment of the joint labour-management Canadian Steel Trade and Employment Congress (CSTEC), the USWA led the way in developing new skills training curriculum, it was the more training-focused Dofasco that was the biggest consumer and user of that curriculum.

Steel2: The NAFTA Steel Industry

The next major stage was the NAFTA Steel Industry which was characterized by a growing pre-occupation with access and penetration of the US market.

The signing of the NAFTA agreement was a pivotal moment for the Canadian steel industry in both its governance and business models. The steel companies felt fundamentally threatened by the rise of American steel protectionism. They fought desperately to find a mechanism to guarantee access to the US market but failed. A decade long struggle ensured to ward off inclusion in anti-dumping cases. The industry ultimately decided that if you couldn’t fight them then you had to join them. The Canadian industry added about 3 million additional tonnes of capacity in the 1990s but virtually all of it was located in subsidiaries in the United States. The strategy was not without commercial success. The most profitable integrated North American

steel maker in the new century was Dofasco in Hamilton. The most profitable minimill was Ipsco in Regina.

At the governance level, the Canadian industry was ultimately successful in establishment of a North American Steel Council (NASC) to include US, Canadian and Mexican producers under AISI sponsorship. Common trade policies against offshore imports were agreed in 2005 by the US, Canadian and Mexican governments. And, in this context Canadian steel producers got an exemption from US trade actions. However by the new century there was nobody home in the US industry. Most of the US steel producers were either bankrupt, taken over or reducing their capacities.

The NAFTA steel industry also marked an important change in steel innovation and knowledge networks. It was a critical change from indigenous development to technology licensing.

> To be clear, the R&D is only 65 people out of 1000, the others are in computer techs, quality, environment, energy and those kinds of things. The research group, although it is still one of the top 3 in North America, we go to France or we go to Japan, and we either trade or buy, or we try and negotiate, and sometimes we will work with the university if we are close and just need a little bit of help. Most problem solving we do internally, but new products, if we can't make them with a profit, then we'll go to France.[3]

The Canadian producers followed the US lead and eliminated basically all there in-house steel R&D capacities. The leader, Stelco saw 100 of its best research engineers leave the company on one day, taking most of the IP with them. They were primarily process engineers. They were regarded as the best pool of steel engineering talent in the country.[4] They moved en masse to Hatch Engineering and built a 700 person engineering practice servicing North American and international steel clients. It was a gain for them but the steel industry and Hamilton were the

[3] Confidential Interview, former Dofasco executive, Oct. 16, 2006

[4] Confidential Interview, former senior Stelco engineer, December 20, 2006

worse for it. Hatch, which services a broader range of clients than just steel, now employees considerably more employees than does Stelco in Hamilton.

Knowledge networks changed because, having abandoned indigenous technological innovation, the steel companies now came to rely on international technology transfer and licensing. At this game, Dofasco proved itself much more adept than Stelco.

> Because our major customers are quite bureaucratic – traditional, conservative, cautious – they don't really want to put a new steel in their cars that no-one else can make, or they've not seen before, and they're not sure how it works. Typically, what happens is that new steels come out of Japan that no one has seen before and maybe they're stronger or thinner or more corrosion resistant or whatever, and the North American companies, say we need this too and ask us to make it so we may come up with our own design or similar design – many of these are patented so you can't use the exact same, so our research is trying to come up with grades that are at the leading edge but are not unique in the world.[5]

Dofasco, by contrast to Stelco's 1000+ engineers, had only 50 metallurgical engineers, and still does. But from the late 1990's, under its strategic plan *Solutions in Steel*, Dofasco re-organized to deploy 1000 people into the field for interaction with customers focused on application development. The Dofasco strategy was to innovate in applications with customers. The deep metallurgical technology developments they relied on from Nippon steel and others.

> We were able to get the two Japanese steel companies to partner with us but in different areas of the plant – they were both nervous that we would give information to the other – so we had Nippon steel working in our steelmaking plant and JFP working in our hot mill and the French would be working in our cold mill and they'd all meet in the cafeteria or in the elevator at the same time – that was always tricky.[6]

[5] Confidential Interview, former Dofasco executive, Oct. 16, 2006

[6] Confidential Interview, former Dofasco executive, Oct. 16, 2006

As a result, the patenting Dofasco did was related to process engineering in support of local customer requirements.

> 98% comes from customers wanting us to replicate Japanese steel. If we went to them with a steel no one else could make, they wouldn't buy it. Historically, our view was that we should protect our IP thru know-how – you just don't tell people what you're doing, but in the last 8 years, we've done more patenting there are two philosophies: one is that when you move quickly, you don't have time to patent, and if you apply for a patent, you're telling people what you do and they can find a little way to get around it; so you just don't tell people – the Japanese are good at this – they call it 'know-how' [tacit knowledge] So that was our philosophy until about 10 years ago when we started protecting property because we got stung a couple of times, when we produced something that we didn't document and they used it and came after us, so now we protect it in our company, we don't have a lot of patents, but we've patented the unusual things, not the extensions…we have partnerships with McMaster and various universities but they're not really innovating new things for us as much as they are helping solve problems that we already have.[7]

Even with the takeover by Mittal, Dofasco's innovation capacities and learning network are being preserved.

> In the steel business, everything happens so fast and its so hot that we need sensors and sensor technology to control everything. It's a very high tech business and computers control a lot of things. For example, 10 yrs ago HP said that Dofasco was its biggest Canadian company because we were doing so much process automation such as mills, hydraulics, and measure temp and speed, surface quality, lasers. In fact, that's where we tend to have a lot of patents in automation technology – its not in the steel product, it is in the sensors used to control the mill to give you the best steel product. We'll take 4 or 5 different types of equipment and we'll put them together in a particular way – e.g. cameras, lasers and computers – and that's what we'll patent.[8]

During this period, there was some important interaction between the steel companies and university researchers and laboratories, notable the Steel Research Centre at McMaster University. However the connection was limited. Stelco played a mostly passive part, funding a

[7] Confidential Interview, former Dofasco executive, Oct. 16, 2006

[8] Confidential Interview, former Dofasco executive, Oct. 16, 2006

Research Chair which stood unfilled for some years and had virtually no participation in on-going continuing education activities. Dofasco had a much more active involvement at McMaster but at the end of the day, their expectation of the university was a flow of well-trained graduates rather than steel technological innovation per se.

> We interact mainly with people at Mac where we have access to the facilities and labs and those are very valuable to us. They have some programmes that we fund but they're more longer term, knowledge for the benefit of the university rather than knowledge we're depending on for tomorrow. We've done the real R&D which is really product development, at home but we like to have good skill sets around us and we like to have the university working in areas that are somewhat related.[9]

The main drivers of steel technological innovation became international consortia such as the Ultra Light Steel Auto Body (ULSAB) which brought together 31 global steel and car companies to sponsor auto steel developments. During the past decade, R&D in the steel industry was overwhelmingly focused on auto-related developments. Steel for cars was the major profit centre for integrated steel producers.

Within these consortia, Dofasco proved to be the best and quickest learner. The drivers of Dofasco's commercial success in the past decade were hydro-forming and tailor-welded blanking. Both were generic technologies they acquired through the research networks but implemented much faster than their competitor/partners. CEO John Mayberry had a vision – Solutions in Steel – published in 1998 of steel innovation analogized to software. The deep metallurgy would be developed by Nippon and Usinor, like the heavy weight OEMs in software – Microsoft, SAP and Oracle. The Canadian producers would be like Value Added Reseller (VARs) developing vertical applications off these platform for use in the local market.

> With respect to customers, they are local, and are between Oshawa and the other side of Detroit, but we also sell steel into California and Mexico – so maybe 20% goes to the US and 80% stays in SW Ontario and Detroit area.[10]

[9] Confidential interview, Welding company executive, October 21, 2006

[10] Confidential Interview, former Dofasco executive, Oct. 16, 2006

Application of these new technology platforms for the auto and related manufacturing firms of Southern Ontario became the steel innovation strategy. It became the basis of Dofasco's success.

Steel3: Global Steel Supply Chains and Knowledge Networks

At the height of its profitability and commercial success in 2006-07, the Canadian steel industry imploded. It was completely taken over by foreigners as part of the global steel consolidation story. The current restructuring stories of the two lead producers portend different futures.
Steel in the Era of Global Steel Supply Chains

The NAFTA steel network has been overtaken by the globalization and merger movement in the international steel industry. We now have neither steel mills or steel companies in Hamilton is any way that was historically understood. As part of a general trend in basic industries, we now have global supply chains and knowledge networks. The former Stelco and Dofasco occupy different positions within these networks.

Stelco now occupies a classic branch plant position. The US Steel takeover has meant largely a dismantling of its engineering and technology capacities, as these activities have been consolidated into the US head office. US Steel (Hamilton) now presents itself in its industrial brochures and website as having innovative products and plant capacities. The recent layoff announcements were accompanied by significant changes to management structure. Quite simply put, US Steel has identified its strategic production assets as Birmingham, Pittsburgh and Gary. US Steel Canada is now consolidated into the second tier Great Lakes Division. It is a B Team asset. Both Hilton Works and Lake Erie Works are now announced for indefinite closure[11].

[11] US Steel, press release March 3, 2009

Dofasco on the other hand is seen as a strategic asset for Arcelor's penetration of the North American Auto steel market. Arcelor Mittal (Hamilton) formerly Dofasco, still emphasizes in its material its innovative R&D capacities. Discussions are currently under way about co-locating one of its global R&D centres with McMaster University and the relocated Canmet labs in Hamilton. There have been no layoffs of permanent employees at Dofasco and local talent has been circulated among Arcelor global operations.

> At Stelco under Mott, there were lots of layoffs in the R&D and development side. It was a continuation of a long process. Stelco now looks more like the classic branch plant.
>
> Arcelor sees Dofasco as a still important part of global R&D and innovation. They talk about sending Hamilton people around the world to other assignments. There are active discussion underway about an auto/steel research centre and it being Arcelor's global auto R&D centre, involving both McMaster and Waterloo.[12]

Industry-to-university links have a long history in Hamilton, particularly with the Engineering Faculty of McMaster University. There is broad and deep agreement in business, academic and policy circles that a critical opportunity for the future of Hamilton's economy lies in deepening and developing linkages and capacities in the Materials and Manufacturing sector.

> The key word here…we need it…is this notion of partnership between the university, government and private industry. Private industry, and remember manufacturing is a very applied form of engineering – it is not basic science, it uses basic science for the purpose of creating some things that are really applicable, so industry by definition has to play a really important role because they give us the relevance of the research, they give us the interesting technical problems that we can work on, so the purpose is not simply to use industry as a source of funding, although they are a source of funding[13].

According to a key academic administrator, it is research engineering capacity in active intellectual and human capital interchange with local industry. This is fertile ground for further examination of the specific field of research engineering. The classic study in this field is Vincenti's *What Engineers Know and How They Know It.*

[12] Confidential Interview, former Stelco executive, November 20, 2008

[13] Confidential interview, university administrator, Oct. 11, 2006

Research administrators are also very specific about what kinds of capacities and knowledge exchange they seek and what they think can be leveraged to maximum advantage in the future.

> we do not have a model of fee for service; the model that we use is essentially a research contract model – there are projects objectives…now some companies fund us sometimes to look at fundamental research issues because it is in their interest to develop a capacity in a particular area[14]

Currently we see the attempt to reconstitute the link between Hamilton steel and the local by building on local universities and public infrastructure. The McMaster University Innovation Park will become home in 2010 to the Federal Canmet metallurgical laboratories relocated from Ottawa. Arcelor is in active discussions with the Ontario government, McMaster University and the University of Waterloo for establishment of a global steel Arcelor research centre focusing on issues of corrosion, manufacturability and steel-composite materials. The metallurgical developments would be at McMaster and the application development at Waterloo. University of Waterloo and McMaster university are the leaders with 78% of the Ontario grants for auto-related research. McMaster will do the metallurgy, given its critical expertise in the next-generation steel production challenge – to replace the blast furnace. UW will do formability and safety issues. UW also has the added advantage of a Math faculty for producing algorithms, simulations, etc.[15]

The larger lesson coming from steel may be that as objects of academic analysis and public policy, we no longer have companies and industries in any traditional sense. For better or worse, we are now decomposing into supply chains and knowledge networks, themselves being nodes in the new Global Production Network (GPN). There is a growing debate in the economic geography literature concerning the dynamics of these developments (Sturgeon 2007, 2008; Rutherford & Holmes 2008). As recent articles point out, global supply networks are not flat, they are contested terrain. The fact is that Stelco and Dofasco are now occupying different positions in these steel supply chains. Dofasco is a strategic asset, Stelco is marginal. The impact of future policy measures will impact differently as a result.

[14] Confidential interview, university Dean, Oct. 11, 2006

[15] Confidential interview, university research manager, December 2, 2008

Hamilton Bio-Medical and Health Sciences

The interviews identified a number of innovative firms, however these were not biotech or pharmatech firms, they are in health services. This may serve to moderate expectations that research universities with large biomedical faculties will necessarily produce a fulsome stream of biotech spin-off companies to fuel regional growth and prosperity. However, this development atleast in the Hamilton case may not be surprising.

> New companies will be service oriented more than biotech. It's investor driven. There are not investors in Hamilton willing to take risks on early stage developments. We need a better funding model. For example, if there was more early stage investment into early validation of genetic marker technology or basic pharma therapy then firms could emerge sooner. It creates a viscous circle. Biotech and pharmatech opportunities haven't emerged because of the gap in the venture capital market.[16]

Health Sciences Network Actors

The Healthcare /Health Sciences cluster in Hamilton appears to focus on testing and treatment. The two most successful new companies are both directly involved in the area of testing. One manufactures antibodies for use in Hemostasis research while the second conducts contract research for several industries, including mining and oil and gas. Several other companies provide products or services related to treatment. We found no pharmacological cluster in Hamilton, though a significant new company supplies regulatory services to the drug industry. Hamilton is home to medical professionals with a variety of backgrounds and specialties, which makes it a good place to recruit workers and to find partners to work together. One example is a spinoff from McMaster University which specializes in measuring the quality of life results from different treatments. Hamilton is known as a centre for health sciences, which makes it easier for certain organizations to promote their services to an international audience.

Hamilton has also has certain special assets that make it a particularly good place to do certain types of research. For example, Hamilton has a nuclear reactor, which is an important part of the

[16] Confidential Interview, Biotech Network Administrator, April 24, 2008

testing performed by spinoff companies. Hamilton citizens also tend to have generous medical benefits from unions and the government which means that specialized medical services – such as designed orthotics – are often paid for. Union health benefits have provided the financial base and market for these emergent health services firms.

Health Science is an emerging, high tech industry that is most likely of the three partner with universities and local institutions, to conduct high amounts of R&D and to create unique products with customers around the world.

Interviewees have identified the unique McMaster Medical School Model as a significant factor. In contrast to other medical schools such as the University of Toronto, McMaster focuses on clinical practices rather than laboratory research as key to its objectives. It should be recalled that the now health policy norm – evidence-based medicine – was invented by two McMaster faculty.

The dynamics of the Health Sciences cluster in Hamilton is effected by more than just the McMaster teaching model. It is also directly impacted by other factors that go to the heart of this study.

At the formal governance level, the present Chair of the Board of Hamilton Health Sciences is Don Pether of Dofasco. His predecessor was Bob Jones of Stelco. Interviews reveal that for the past decade, the Chairs of the Board and all of the key Committees have be executives from the steel companies.[17]

At the other end of the scale, interviews also reveal that it is the well-endowed health benefit plans of the USWA and CAW in Hamilton that have largely created the market for the new innovative health services firms to come to the market with new customizes prosthetics, specialized testing technologies and procedures, etc.

[17] Confidential interview, HHSC Board member, November 27, 2006

Key informants have also identified that this collective agreement-based financing has made up for gaps in the local venture capital markets. Innovators, even where they may involve a medical device or technology of some kind, have developed service based business models in order to fund their next generation development. It is certainly an irony and counter-intuitive that these 'smokestack' industries and particularly their much criticized legacy cost structure is funding health innovation[18].

The Strength of Linkages Between Local and Non-Local Actors

The Jane Jacobs model of urban knowledge networks is that individuals in a vibrant and diverse urban environment interact with each other on a regular basis and help different types of companies improve the quality of their product and business processes. In the interviews we found that this was not necessarily the case. There were a variety of knowledge networks that were used to solve problems and develop new ideas. Those geographically local were often less relevant than many others.

The Hamilton Network agents include:

Internal, International Network (Large Organizations) Agents:

In large MNCs such as engineering, manufacturing and processing, individuals with a problem to deal with, or a new idea to develop, will typically turn to others in their own organization, often sourcing talent from the corporate head office and other locations around the world. In some cases, there are regular visits and meetings used to exchange ideas, see what others are doing and offer advice.

External, International Networks Agents :

Individuals who are not part of a large organization may also consult an international network of contacts. These are often co-workers from past jobs, friends from school or colleagues met at a trade show, conference or professional organization. Often a quick phone call or email are

[18] Confidential interview, biotech manager April 24, 2008

enough to get a solution to an issue. The Internet is a vital tool in this regard as well, as discussed below.

Local Informal Networks Agents:

Several questions in the interview guide prompt the interviewee for information on local, informal connections, with the idea that an organization benefits from cross pollination of ideas from many different sources. We found however, that there was much less of this sort of interaction than one might expect. Very rarely did an individual point to a specific activities they engaged in or companies that they interacted with who provided them with product ideas.

The cluster for whom the local context was most important was the artistic community, which in many cases lived up to the ideas of cross-pollination and idea generation that lives up to the Jane-Jacobs model of urban innovation. Artists, arts organizations, and even craftspeople such as woodworkers regularly interact with each other, develop events together and, to some degree strategize with each other. Artists, for example noted that galleries, shows and discussions with other artists all influenced and improved their work.

In other clusters, where local knowledge was shared it was typically regarding how to better run the business: key personnel recruitment, finding land, and for small businesses, sales and marketing skills. For example, an executive from a diagnostics company noted that attending her son's sporting events gave her a chance to speak to other small businesspeople and get new ideas.

Similarly, an service sector entrepreneur identified unrelated events like the boat show as places to learn about marketing one's product.

Government Support and Local Organizations

When asked about help from the government or local institutions, many organizations initially responded by saying that the government played little beneficial role and that they had little

involvement with local institutions. After further discussion however, many described certain government programs as beneficial in a variety of ways, most notably in providing networking opportunities with other similar organizations. Again, product development was not the core benefit, instead the goal was to learn how to run their business better. For example, contacts helped to facilitate tours of different plants, which allowed companies to see how others were making their operations more efficient. Institutions like the Hamilton Incubator of Technology (HIT), played a similar role. A regulatory services company that originally began there, identified the incubator as a place to learn about putting together a business plan, accounting, finance and HR.

At an individual level, groups like the Professional Engineers of Ontario (PEO) were useful places for professional development and support, with conversations on specific topics less common. However, membership in the PEO may help engineers develop personal relationships that they may then call upon when a project issue arises.

The Internet

Early on, two different interviewees identified questions on the role of the Internet to be something that was missing from the questionnaire. We subsequently discussed the Internet with all future subjects and virtually all identified it as an important problem solving tool. The main uses identified were:

Finding Skills and Gadgets:

From a manufacturing perspective, projects occasionally require a skill, a tool, or a machine that the principal organization does not possess. The Internet was identified as a place where one could easily find the ‘gadget’ that you are looking for, contact
the company that makes it and see if it will work with your machinery. The same holds true for finding companies with particular skill sets.

Answering Questions:

Chat groups and knowledge databases exist for many technical specialties and sub fields. An engineer or researcher trying to solve a particular problem can post a specific, technical question that will be considered by potentially hundreds of peers and answered quite quickly. According to one interviewee;

> We use it (the Internet) very extensively here. There are listservers for example on a particular topic. If you have any questions on a specific technology just put your question up and you'll get answers from around the world about how to solve the problem.[19]

Expanding Ideas:

At least one interviewee suggested that "playing on the Internet" was a valuable process in and of itself, as a way of expanding the creative thinking abilities of employees.

Trade Shows / Academic Conferences / Art Shows

One of the most interesting commonalities between organizations in terms of knowledge networks was the importance of conferences and trade shows as sources of new ideas and relationship building. This was true for organizations in all sectors. The chief difference between the organizations was the nature of the event. For those in Health Science the events are academic conferences, where peer reviewed research was discussed and papers presented. For artists, it is galleries or theatre events that give an opportunity for socializing and inspiring new ideas. For manufacturers, the forums were typically trade shows, organized by a particular trade association, where companies displayed their new products. While the shows are ostensibly to display products to customers, or to share research, they were often even more valuable as opportunities to reinforce connections with distant personal contacts, to find potential collaborators, to see what your competitors are doing, or simply to prove, as one gritty moulder suggested, 'that you're not dead', because everyone in the industry goes to the show.

[19] Confidential interview, manufacturing executive June 2008.

One particular trade show that was strongly recommended was the Hanover Industrial Fair in Germany. This fair is an opportunity for university groups and other IP dealers to show off their products and auction them to companies who may have a use for them. One manufacturer uses it to find ideas for improving his products – machines for putting soft products into shipping containers:

> Let me say this into the microphone - send all of your people to the Hanover Industrial Fair and go to the R&D centre. Absolutely critical. You'll understand philosophically why the Japanese and Germans are so good at it....This is the world's biggest industrial fair. They had two buildings of R&D stuff. One was just for cool design - from an iPOD to a bicycle...The University of Dresden had a tent there that would span 100 meters.[20]

Tim Horton's and Local Establishments

An interview subject mentioned that the local Tim Horton's had been a fruitful recruiting ground for him. While standing in line waiting for a coffee, he would converse with others that he knew, mention a particular need, and learn that either the person that he was talking to was currently between jobs, or knew someone else who was available.

This interaction led us to ask subsequent interview subjects whether there was some regular local establishment or event – a coffee shop, a bar, a church, a softball team, an art gallery – where they often ran into others and spoke about their business. In some cases, the individual that we spoke to was particularly involved in their community and they did answer in the affirmative.

For example, an arts managers conversations at the softball diamond, as discussed above. Another interviewee who was heavily involved in his church mentioned that he has some work-related connections there. In general though, the responses to this question tended to be negative. For most people, there was no common, casual location where they would just sit around and talk shop.

[20] Confidential interview, manufacturing executive, Sept 2007.

An interesting perspective on this question came from an engineering consultant. He noted that in the past, the company's offices were located in downtown Toronto, at Yonge and St. Clair. A few similar organizations were located nearby. At the end of the day, engineers would often walk to a nearby bar and have a drink together. Since that time however, the company has moved to a large building in a Mississauga industrial park. While the company is still located near a number of similar organizations, the physical distance between the buildings is much greater and there are fewer interesting places to go.

He mentioned that the industrial park did have a restaurant that the managers intended as a place for workers to gather and chat over lunch. However, the quality of the food was mediocre and the size of the industrial park was such that one had to drive even to get there. Once you were in your car, there was no reason to settle at this establishment, when you could go down the street to somewhere better.

A couple of other reasons suggested for the lack of a central meeting spot was that engineers were by nature just not as social as others, or that because the individuals being interviewed tended to be senior individuals and therefore older, they no longer had the type of lifestyle where they would pop down to the local bar after work. There may in fact be other engineers in their 20's who do frequent the bars in Mississauga and spend a lot of time together.

Hamilton does appear to have a strong, growing and connected visual art scene, particularly in the downtown part of the city. Other important arts institutions include the Hamilton Art Gallery, the Imperial Cotton Centre for the Arts (ICC) and the Dundas Valley School of Art (DVSA). Interviews seemed to be better connected, giving much broader references and suggestion for other interviewees than other sectors.

Many artists were located in converted industrial buildings and downtown storefronts that would be unaffordable in larger cities. Rents for apartments are also much lower. Many of the artists that we spoke to found the industrial architecture and its gritty personality to be inspiring and more 'real' than other cities they had worked in. Certain factories and old buildings provide particularly good backdrop for films and still photography. Hamilton's successful urban past

gives it positive characteristics, including compact downtown, with many shops and services, and long tradition of major art institutions. Perhaps most importantly, it has a unique identity that makes it distinct from newer, suburban centres such as Mississauga. The impact of the arts community on the broader Hamilton economy is unclear. There is anecdotal evidence that filmmaking work is moving into the city, because it offers similar urban environment as Toronto, but at lower cost. Discussion with the one of the arts centres also noted that artists there were working with companies in the area on marketing projects.

Implications of Findings for on-Going Research and Debate

This summary of the findings in the Hamilton case correlates with three significant themes in the literature.

1. Global/Local Knowledge Flows

Previous work on the steel-auto cluster documented linkages between Canadian integrated steel producers and the auto industry, particularly research and development initiatives within the steel companies and with global consortia such as ULSAB. The difference between Stelco's traditional indigenous research efforts through StelTech for example was contrasted with Dosfaco's technology transfer strategy. This placed Dofasco in a more advantageous position to pursue an innovative product development strategy with its Ontario regional customer base. However, it also meant that the university research base at McMaster lagged behind more advanced developments at Carnegie Mellon and University of Pittsburgh.

Global/local knowledge flows are now undergoing another major shift. The steel producers have themselves now been directly integrated into the global steel production networks (Sturgeon et al) via mergers and acquisitions. The local knowledge networks and public research capacities are now trying to catch up through the relocation of the CANMET labs, negotiations over an Arcelor-McMaster research centre, etc.

2. Knowledge Spill Overs: Specialization/General Knowledge

Most of the literature on knowledge spillovers via labour market developments have focused on the supply side. Studies have examined the transfer of human resources and skills through the dislocation/relocation of human factors between old and new economic sectors and companies. The role of unions and whether 'unions make a difference' has primarily examined the net flow of skills and human resources on the supply side.

The unique feature of Hamilton that is emerging is the impact of unions and old economy labour market institutions on the demand side. In Hamilton, it is exactly the financial base of union health benefit plans that have generated the market for innovative firms to emerge in the health services sector. Among other things, biotech firms are developing health service business models to make up for deficiencies in venture capital markets to fund new devices and procedures. The Hamilton Health Sciences complex is a source of ideas, but it is union collective agreements that are enabling the innovation to actually be implemented.

3. The Role of Public Research Infrastructure

Research infrastructure, public and private, will be critical to the future of the Hamilton economy.

The old economy model assumed a linear model of research and innovation. Research took place in the primarily in the R&D labs of the companies such as Stelco which were then transferred internally for commercialization. Dofasco extended the scope of innovation by reaching out through technology transfer agreements and international industry consortia. In the new globalization phase of steel, but also in biotech, fibre optics, etc. we have witnessed the emergence of asymmetric knowledge networks. That is, innovation in the future will be non-linear and come from multiple centres of knowledge generation, with each specializing in different aspects of development.

Hamilton Knowledge Networks

How should we understand knowledge networks in Hamilton and what should we expect?

Recent work by Phil Cooke has challenged our conventional assumptions about learning organizations and learning regions. The fault line in past academic and policy approaches is the asymmetric nature of knowledge and knowledge transfer. Knowledge is neither uniform nor ubiquitous. Within “learning companies”, expectations have floundered on inertia and interests within the firm. Within “learning regions” asymmetries of knowledge and institutional

configurations between firms have led to shortfalls in expected knowledge spinovers (Cooke 2005; 2007a, 2007b).

Cooke (2005) argues that a qualitative shift has taken place in the dynamics and drivers of globalization and the local/region capabilities. Globalization 2, he argues, is characterized by a shift, whereby the advantages of scale which favoured global corporations, has now been counter-balanced by to dependence on regional knowledge capabilities. Following on Penrose (1959/1995) the dynamic capabilities of the firm reside in knowledge networks leading to the massive increased value of transferable knowledge to the wider economy of the firm. Cooke extends the argument to formulate the proposition that 'Globalization 2' is driven by the quest by multinationals for exploitable knowledge in 'knowledge regions' often dependent on public research funding resources. Increasing returns to scope and scale give the character of 'spatial knowledge monopolies' knowledgable clusters and their broader regional innovation systems. He argues that many industries show large scale corporations having become supplicants to small 'scale' knowledge-intensive firms and clusters due to their asymmetric knowledge weaknesses.

> The take over of Dofasco may be to the better in the long run. Arcelor is making available its global researchers on high strength steels and micro-structures for use in Hamilton and with McMaster. How ever the diffusion out to the companies may take a long time, more of it because of cultural limitations and attitudes that are big restraints on the appetite for technical innovations. [21]

This does support the notion of the recent takeover of Hamilton steel companies by new global steel titans, atleast in the Dofasco-Arcelor case, are taking place within the dynamics suggested in Cooke's Globalization 2. Conversely, the aspirations of the McMaster-Waterloo auto-steel research consortium confirms the other side of Cooke's asymmetric knowledge dynamic.

The asymmetry goes to the nature of knowledge itself. The Regional Innovations System approach is not particularly predicated on learning, but rather on knowledge and innovation. Knowledge exploration and knowledge exploitation are strategic choices for organizations.

[21] Confidential interview, government science consultant, April 25, 2008

Successful regional innovation systems have organizations that conduct research that generates new knowledge in appropriate institutional settings. And other organizations, mostly firms, commercialize this knot consumable innovations in the marketplace. Cross-boundary mechanisms or 'bridging social capital between research (exploration knowledge) and commercialization (exploitation knowledge) are critical to success. Further, the latter can be entrepreneurial (ERIS) or institutional(IRIS).

In the steel case of Steel2 and Steel3 when the Hamilton steel industry's knowledge networks became significantly non-local, the technology licensing and transfer mechanisms and participation in the ULSAB, can both be seen as examples of ERIS bridging mechanisms. The movement of key talent and IP from Stelco to Hatch for subsequent commercialization can be seen as part of the same trend. All of these knowledge transfers were taking place within contractual framework of private firms.

The present move to use public infrastructure and university-government research capacities with the proposed Arcelor research centre partnered with McMaster, Waterloo universities and the Canmet labs is clearly of the IRIS bridging mechanisms.

Finally, the current changes underway in Hamilton as local steel capacities have been globalized and configured within global supply chins for really the first time, would confirm Cooks hypothesis that the configuration of local knowledge capabilities underpins the way in which globalization proceeds.

	Steel 1	**Steel 2**	**Steel 3**
Anchor Firm	Stelco	Dofasco	Arcelor
Market Orientation	Local	Continental	Global
Bridging Mechanism	Proprietary	Private Consortia	Open Source
Exploratory Knowledge	In-house	Licensed	Public infrastructure
Exploitative Knowledge	Individual customers	Regional	Global Supply Chains

This is the more complex setting and potential excitement of the new McMaster Innovation Park and relocated CANMET labs in Hamilton.

Global Supply Chains

Unlike the last 30 years in the economic history of Pittsburgh, Hamilton has retained it steel production capacities. However the configuration of production capabilities, business functions and governance have changed radically. The Stelco's and Dofasco's were always referred to as integrated steel companies because they housed the complete range of production, marketing, sales and corporate functions in one vertical entity. The take over by Arcelor and US Steel have most obviously changed the governance structure, but perhaps more importantly has been the re-configuration and placement of these facilities as nodes in the production networks of the new global steel industry.

How should we understand this qualitative shift? Sturgeon (2000) usefully distinguishes between:

> Value Chain: a sequence of productive, value-added, activities leading to an end use or product;
> Production Network: two or more value chains that share atleast one actor or network linkage

As the North American basic steel producers in the 1970s and 1980s increasingly focused their research and production of sheet steels on the needs of the auto industry, they in effect began to 'dis-integrate' from traditional integrated steel producers into part of the value chain of the auto OEMs. The shift to a NAFTA steel industry meant that the Canadian producers focused primarily on continental markets but also added significant additional production capacities in the US and Mexico i.e. Stelco (Oregon Steel), Dofasco (Galatin, Monterrey), Ipsco (Iowa, North Dakota, Alabama).

However, these developments were overtaken by the globalization of the steel industry in the past decade. As happened in electronics, auto and other industries, new global consolidators pursued regional global production strategies i.e. locating atleast one plant in each of that major trade blocks (North America, Asia and Europe) ensuring market access and adequate economies of scale.

The relevance of these developments for the purposes of this study is that global-scale value-chains and production networks have come to act as mechanisms to weave together various specialized industrial clusters, giving rise to a *network of clusters* (Sturgeon 2000). This appears to be the most appropriate conceptual framework for understanding the recent, rapid (2006-08) take over of all the major Canadian Steel producers: Stelco (US Steel), Dofasco (Arcelor), Algoma (Essar) and Ipsco (SSAB/EVRAZ).

Gereffi, Humphrey and Sturgeon (2005) discuss the variety of governance models that have merged in the evolution of global supply chains. The varieties of governance is driven by three key variables: (1) the complexity of inter-form transactions; (2) the degree to which this complexity can be mitigated through codification; and (3) the extent to which suppliers have the necessary capabilities to mete buyers' requirements. It is very early in the development, but as a first approximation, the integration of Stelco can be seen as insertion into a hierarchical model of governance. The integration of Dofasco can be seen as entry into a relational model of governance.

Further Research: Waterloo, Hamilton and IP Policy

Finally, Hamilton-Waterloo comparisons inevitably arise as an important contrasts in the economic geographies of innovation. It is relevant to contrast the different IP regimes of the universities in the two regions. It has become conventional wisdom that a critical success factor in Waterloo's success is the difference in university IP policy. Waterloo, unlike other Canadian universities, allows the inventor to keep the intellectual property rights. Many attribute the huge number of successful spin-off firms in the Waterloo region to this single policy difference.

There is no doubt that McMaster University follows the traditional Canadian university IP policy model.

> the IP belongs to McMaster, we don't have the system where the IP belongs to faculty, but if there are financial gains resulting from the IP, the lion's share goes back to the faculty member who created the IP. In some cases, it might result in joint patents between university researchers and people in industry and these are usually handled on a case by case basis[22]

The Waterloo model may be validated in fact in the one case discovered to date in Hamilton of a bone fide biotech spinoff firm from McMaster – a microbiological filtering process. The inventor/owners fought a long and contentious, but ultimately successful campaign to get the same deal as Waterloo. The inventor and his business secured and retain the IP rights to the invention. This may validate the concern about IP regimes in research universities.

However, recent work (Bramwell & Wolfe 2008) cast a more critical perspective on Waterloo's development, looking instead and more recently at things like the flow of highly trained graduates, the Waterloo business environment and civic governance and traditions.

Nonetheless, in the specific Hamilton case, the majority of successful health services firms in Hamilton appear to fall outside of the IP policy debate. The service models they developed largely depend on tacit knowledge techniques - how to do it – which are probably not patentable in any case. They are either communities of practices such as prosthetics, which have ties in part

[22] Confidential interview, university administrator, Oct. 11, 2006

some of the traditional moulding industry in Hamilton. Or, they have made synthetic knowledge transfers such as generic eye washes but delivered in proprietary forms.

Synthetic and tactic knowledge transfers were also reflected in Manufacturing firms outside steel and health.

> Our main source of competitive advantage is technology, application, design and quality. We introduced our system in 1990 way ahead of anybody else. That's how we made our mark but the fact that we understand how to weld these parts better than other people do – we have a reputation for running systems that work and we control the technology from software to hardware, everything is done by us.
>
> We develop mainly in consultation with customers. We have our own IP based on what we see in the market and we get it by talking to customers, going to trade shows, seeing what the competition has, talking to key people in the industry to see what they want to see.[23]

[23] Confidential interview, Welding company executive, October 21, 2006

Conclusion: From Steel to Health ?

All of this returns us to our opening point. There are robust knowledge networks functioning in the Hamilton economy. However they work internally in different ways and research has identified several unanticipated interactions between clusters as apparently disparate as steel and health.

The original hypothesis was: That the performance of City Regions depends on: the density and/or local networks; the mix of local and non-local actors; and the heterogeneity and diversity of actors. All three propositions appear to be true for the City of Hamilton. However, the mix and configuration of these vectors makes all the difference an challenges for the desired outcomes.

Based on the celebrated example of Pittsburgh and Carnegie Mellon, may we expect that Health may replace Steel as the leading economic sector in Hamilton?

The McMaster Health Sciences complex if certainly an important focus on employment and intellectual activity. However, little by way of biotech spinoffs and entrepreneurial activity have come to pass. The teaching model of McMaster may be a factor. There are startup companies but they are in testing (labs) and regulatory compliance domains, not hard science/discovery.

> The McMaster Teaching Model is a good thing. The opportunity there is not as recognized as MaRS. A lot of it is social networking e.g. MySpace. Opportunities that come out of service models and knowledge networks are not just technology plays. It is not just a high profit venture model. Innovators may be not-for-profit, innovating for a new social context, social networking and social oriented technologies. There are different types of technologies coming out of McMaster. For example, current HHS is working on techno-logistics for patient management in hospitals of pre/post-operative pain.[24]

[24] Confidential Interview, Biotech Network Administrator, April 24, 2008

The MaRs model fundamentally assumes that analytic knowledge spinoffs from research universities results in direct entrepreneurial gains in new company spinoffs and technology development. Perhaps this is fundamentally wrong. As Meric Gertler's distinction between analytic and synthetic knowledge networks may be key to the difference. On the other hand, if the McMaster Teaching Model is the anchor of the Hamilton health Sciences Network, then the creation of Medical Services spinoffs makes sense. This may mean that both Hamilton knowledge networks – material science/manufacturing engineers and Health Sciences/Medical Services physicians are more alike than different.

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