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NETWORK STRUCTURE OF AN INDUSTRIAL CLUSTER: ELECTRONICS IN TORONTO

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Abstract - The literature on the theory of regional industrial success, including that focused on regional innovation systems, provides the conceptual foundation for this exploration of the extent to which firms in clusters of advanced technology industry depend on inter-regional sources for a wide variety of knowledge inputs to support innovation. The substantive focus is the electronics cluster of the Toronto region, Canada's largest manufacturing center. A small, stratified sample of establishments drawn from this cluster is used to verify the importance of external sources of material inputs, and other knowledge sources and the strength of distant market connections. Inter-regional and local collaboration vary in importance as a result of scale-dependent resource differences between firms and in response to choices associated with foreign rather than domestic ownership. The results support the rejection of simple models of clusters and learning regions in which internal connections are privileged over inter-regional and international transactions operating either between or within firms.

Keywords: Toronto, Canada; clusters; advanced technology; knowledge inputs; innovation; survey

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Over the past two decades there has been an international surge of analytical and policy interest in the "knowledge-based economy" in which firms are engaged in the production and adoption of new technologies, and the innovation and re-innovation of industrial products and processes. Innovation by firms, across the range of technologies from traditional to advanced, is conceived as part of a learning process, which may be incremental or reliant on new developments. Simultaneously, there has been a renewed interest in the geographical clustering of industrial firms in core regions and in major cities within them. This means there has been significant refocusing of research on how agglomeration economies and innovation sustain nodes of industrial activity. Industrial clusters, regional innovation systems, and industrial districts are the most common regional industrial models in use and though they tend to have different applications their developers have focused on bonds between firms and with other institutions within regions. The concept of globalization, however, recognizes the ease with which goods, capital and ideas move at the international and inter-regional levels and there is a need to integrate this reality into models of industrial clustering by considering the network choices of industrial firms.

In this paper I identify recent literature that breaks with conventional models of regional industrial systems, especially industrial clusters, in order to provide a clearer recognition of the importance of inter-regional (including international) inputs of industrial knowledge, product market connections, and other inter-organizational relationships. Then, I develop a case study of the knowledge networking of firms in the electronics cluster of the Toronto metropolitan region. I evaluate the significance of inter-regional compared with intra-regional bonds and whether they vary with the organization and ownership of firms, company scale, and the different business environments in which firms exchange knowledge. The conclusion of the paper includes a brief consideration of the policy implications of the research results.

EMERGING IDEAS IN THE INTERNATIONAL LITERATURE

Over the last decade, there has been a renaissance of studies in economic geography, other disciplines and in policy circles in which the connection between industrial growth and innovation is seen to be closely associated with spatial clustering. Contemporary ideas on industrial clusters and regional innovation systems have converged and it is important to record the transformation of the concept of industrial district as applied to the industrial specializations of metropolitan centers, and the relationship between regional innovation systems and industrial clusters. Two major themes are drawn out of this review – first, the vastly increased importance attached to the accessibility to knowledge, reflecting the salience of the industrial innovation process. Second, the inter-regional geography of knowledge connections and other economic relationships provides essential support for innovation systems or clusters regardless of the depth of local resources.

Agglomeration and Industrial districts

The localization strand of agglomeration theory assumes clusters of firms are large enough to generate local economies of scale and scope. Industrial districts have been taken to mean the localization of small and medium-sized firms in one or a set of related industrial activities where co-located firms have established complementary relationships; variants of flexible specialization describe their systems of industrial organization (Brusco, 1982; Piore and Sabel, 1984; Best, 1990). A social-institutionalist perspective has been developed to describe community-based social relationships, which underpin the enhanced degree to which there is cooperation between economic actors (Staber and Morrison, 2000). Industrial districts are exemplified by networks of small firms in the "Third Italy", though elsewhere – in Baden-Württemberg (Germany) for example - small firms are contractors to large enterprises in the machinery and automobile industries (DiGiovanna, 1996). In North American research, industrial districts initially were associated with an account of vertically disintegrated industrial arrangements found in a variety of production systems in metropolitan Los Angeles (Storper and

Christopherson, 1987; Scott, 1988). This form of industrial agglomeration was explained as the outcome of the minimization of transaction costs that results from an increased division of labour and substantial local inter-firm flows of inputs and outputs (Williamson, 1985; Storper and Scott, 1995; Storper, 1999).

Many industrial regions, however, do not conform to any of these models in terms of the size-mix of firms or strong local interdependence (Llobrera, Meyer and Nammacher, 2000). Even in high-technology manufacturing industries there are regional contrasts. Boeing, the dominant firm in Seattle's aerospace industry has allowed only restrained local contractor ties unlike the tiered, regional networks of Los Angeles (Gray, Golob and Markusen, 1996; Markusen, 1999; Scott, 1992). Yet, the Seattle pattern is similar to that of other advanced manufacturing centers in North America, which are neither "core high technology areas" nor merely engaged in fabrication (Lyons, 1995; Manzagol, 1991).

Limited inter-firm interdependence in regional production systems may be common, especially among innovative high-technology firms, and it is now recognized that the agglomeration of substantial parts of the high-technology sector, and supplier-intensive activities such as equipment manufacture, often occurs without overwhelmingly dense regional, input-output networks¹. One outcome is a renewed sense that urbanization economies may be the more apt description of the locational advantages of industrial concentrations of firms in metropolitan regions (Harrison et.al., 1996; Suarez-Villa and Walrod, 1997). Large urban regions provide a diversity of opportunities for firms to find skills, markets and inputs that promote or sustain

¹ See Storper (1999) and Maskell and Malmberg (1999), Yeung (2000), Cooke (1998), Park (1996), Markusen (1996). Evidence on specific regions and industries is found in Angel and Engstrom (1995), Simmie (1998), McCann (1995), Coe and Townsend (1998), Simmie and Hart (1999), Grotz and Braun (1993,1997), Staber (1996), Larsson and Malmberg (1999), and Suarez-Villa and Karlsson (1996).

industrial innovation. Research has turned, however, towards examining the importance that local sources of knowledge may have in sustaining industrial clusters and the most powerful version of that focus on the knowledge economy of regions is the literature on regional innovation systems.

Regional Innovation Systems

Initiated by Freeman (1987) and Lundvall (1988), the concept of national innovation systems focuses on differences in the interconnections of producers and users of innovative products, and between the creators, disseminators, and users of new industrial knowledge. This involves the relationships of firms with each other, and with research and educational institutions, sources of finance, and the development of institutions and business practices as mediated by nationally distinct policies (Nelson, 1993; Lundvall, 1992). The recognition of national differences in innovation practices and outcomes inserted a very broad sense of place into the theory of innovation. Simultaneously, highly innovative regions such as Silicon Valley and the Route 128 zone of Boston stimulated research on the importance of innovation to the vitality of industrial regions (districts), and the role of clusters in driving national innovation systems (Saxenian, 1994; *The Economist* 2002). The consequence is that the theory of innovation gains a spatial dimension, which is achieved through the following:

- Three knowledge intensive processes have become core ideas in innovation theory – feedback from the market, the stimuli of new technology for industrial developments, and the cumulative influence of incremental changes in products and product families (Freeman and Perez, 1988; Gardiner and Rothwell, 1989; Lundvall, 1988). The search for regional connections between economic activities in new rounds of innovation is guided by the chain-link or coupling model which allows for the iterative form of re-

innovation (Kline and Rosenberg, 1986; Rothwell, 1986). At the regional level this model may be used to direct the search for structural relationships².

- The spatial concentration of skilled and knowledgeable labour which facilitates the local accumulation and flow of knowledge necessary for the redesign of products and improved processes is viewed as depending on universities and colleges, on-the-job training and experience and job mobility,
- The possibility that many economic relationships have a social basis, which plausibly reflects relationships built on the basis of proximity, adds an additional locational influence to the course of the innovation process (Grabher, 1993; Granovetter, 1985; Asheim and Cooke, 1999). In particular, collaborative forms of knowledge exchange may involve local alliances between firms and/or R&D contracting between firms or with other institutions.
- Policies to increase the propensity of firms to undertake to increase the rate of innovation frequently are implemented at the regional level and following Cooke (2001) the term Regional Innovation System is applied only to jurisdictions with policy-making powers.

Industrial clusters

Through the 1990s, the clustered locational basis of the majority of innovation systems received explicit attention producing the dominant view that innovation is closely associated with places in which relevant economic resources are most easily accessed by firms that are in close proximity to each other. The contemporary focus on clusters as objects of analysis owes much to Porter (1990) who emphasizes four local factors interrelated within a "diamond" of related and supporting industries, factor input conditions (including scientific and technological infrastructure), firm strategy and rivalry, and demand conditions. Porter is concerned with the

² A longitudinal approach is also possible following the path dependent (historically contingent) nature of innovation.

dynamics of clusters thus his thinking is tied directly to ideas on regional innovation systems. His ideas have garnered substantial attention in policy circles³, and this is probably because the locational components of his diamond such as the presence of capable, locally based suppliers, and vigorous competition among local rivals are expressed in normative language⁴. In many clusters, however, some of these local diamond conditions are weak suggesting a mismatch between observed relationships and the way Porter's expectations are constructed. The need for "sophisticated and demanding local customers", for example, is met much easier when a national or large regional definition is used for the cluster rather than the local scale. In this and other ways, Porter's model strongly reflects a large economy perspective and may not be a good fit to metropolitan scale research in a small open economy such as that of Canada, which is dependent on its international trade. The term cluster, as used here, is a recognizable industrial strength of a particular urban region (whether one industry or a group of related activities). It is a form of industrial organization that relies on networks of highly specialized, inter-related private sector firms and public sector institutions whose final production reaches markets outside the metropolitan region (Egan, 2000).

Shifts towards a knowledge focus

The absorption of a deep interest in the regional incidence of innovation has shifted the way agglomeration economies are described and analyzed. In particular, attention now is placed much more clearly on the way knowledge is accumulated and exchanged and the possibility that proximity is important in these processes.

³ The concept of (industrial or innovation) clusters has been adopted in public sector research; see Malmberg and Maskell (2002), OECD (2001), Information Design Associates with ICF Kaiser International (1997).

⁴ The normative perspective is central to this conception of clusters; for example, sourcing outside the cluster "is not the ideal (first best) outcome" and should occur only if competent local suppliers are unavailable (Porter, 2000).

The proximity thesis - The basic proposition supporting the importance of proximity is that when firms need to acquire knowledge from partner firms or research institutions "dialogue and exchange of information...is less expensive, more reliable and easier...locally" (Maskell and Malmberg, 1999). Furthermore, the geographic concentration of face-to-face partners might reduce problems of interpretation and precision of meaning when new knowledge outputs (especially R&D results) are exchanged (von Hippel, 1994; Feldman, 2000). Knowledge spillovers - informal benefits derived from the R&D activities of other firms and other knowledge generators - are also thought to take place through transfers of tacit forms of knowledge transfer (Feldman, 2000)⁵. This may occur through localized inter-personal knowledge flows (Saxenian, 1994) and gossip and rumour maybe involved (Henry and Pinch, 2000). Maskell (2001) takes this idea a step further when he argues that, without interacting in direct fashion, firms can observe the experiments of other firms tackling technically similar problems of development, design, and production⁶. Intangible forms of knowledge, described as untraded interdependencies by Storper (1999), may garner more research attention in the future but Howells (1999b), for one, indicates there are grounds for being skeptical about progress in research on intangibles and Arundel and Geuna (2001), in particular, argue that little research really analyzes why proximity is important.

Nevertheless, local flows of knowledge are privileged in the concept of the learning region, which is built on the thesis that innovation (both incremental and radical forms) is the most important process in a competitive system of industrial production (Lundvall and Johnson, 1994; Morgan, 1997). This incorporates several familiar elements of regional economic success such

⁵ Citations of local patents and patterns of inter-firm mobility of patent-holders in biotechnology and semiconductors support cross-sectional regression analysis by Feldman (1994); see Jaffe (1989), Jaffe, Trajtenberg and Henderson (1993).

⁶ Carmagni (1991) and Maillat (1991) also describe some of the ways firms benefit from the immediate environment or industrial milieu.

as localized producer-user networks, and regional professional, business, and social relationships, which may assist the fluidity of intra-regional connections. The concept of learning region, indistinguishable from dynamic agglomeration economies (Harrison et al, 1996), has its supporters (Florida, 1995; Storper, 1999; Maskell and Törnqvist, 1999; Edquist, 1997; Gertler, Wolfe and Garkutl, 2000; Wolfe, 2002; Ashiem and Cooke, 1999). Not all evidence, however, points to the necessity of strong local knowledge links for innovative industries or regions. Apparently, shifting the research focus from flows of goods, in an input-output sense, to knowledge flows does not establish a new beachhead for the thesis that strongly localized networks are required for the production and support of agglomerations or clusters or districts.

Looking outside the region – There has been a strong preconception that local interdependencies are of preeminent importance in understanding regional industrial and innovation systems (Nauwelaers and Reid, 1995). Arguably, this has led to inadequate accounts of the openness of regional economic systems to exchange and collaboration (Markusen, Lee, and DiGiovanna, 1999). This is unsustainable as a variety of organizational, communication, and transportation innovations have significantly reduced the role of proximity in the way firms organize inputs from producer services, supplies of material components, systems of contract manufacture (Sturgeon, 1997), and R&D through partnerships or contracts (Howells, 1999a).

The relevant principle is that spatial systems connecting firms with each other and with other institutions may stretch from the local to the global scale (Oinas and Malecki, 1999).

Accordingly, it is misplaced to expect significant inter-firm relations and the learning process to be spatially confined (Clark, 1993; Oinas, 2000; Edquist, 1997) and it is quite reasonable to find firms in identifiable industrial districts with strong external industrial networks (Isaksen, 2001).

Alliances among firms in the U.S. semiconductor industry, for example, exhibit an enormous

spatial range of inter-urban connections (Arita and McCann, 2000) reflecting the existence of multiple sites of innovation, a pattern that is true for most industries. These locations will exhibit different orders of importance - only some will be "product pioneering" locations (Amin and Robins, 1990). Nevertheless, all will contribute to, or share, the "conventions", common rules of action, and communication "codebooks" that are used in particular fields. Thus physical proximity may well not be a requirement for successful interpersonal sharing of knowledge though professional or industrial proximity is necessary (Rallet and Torre, 1999). Thus, using the internet, e-mail, and telephone, many forms of knowledge can be exchanged at a distance given appropriate levels of understanding⁷ (Arundel and Geuna, 2001; Breschi and Lissoni, 2001). It follows that conventions of communication within individual and convergent technologies act to assist the transfer of knowledge to qualified partners wherever they are located.

There will be circumstances when inter-industry or cultural divides are crossed and new conventions may be encountered. Gertler (1995) for example, has shown that the successful deployment of heavily embodied technology such as machine tools is problematic in regions that have a different labour market and industrial culture. Nevertheless, research has moved towards a more balanced perspective that suggests we should expect industrial clusters and learning processes to be sustained by a variety of external and internal relationships (Grabher, 1993; Howells, 1999b; Bramanti and Ratti, 1997). While these arguments run counter to the hypothesis of strongly regionalized knowledge systems and the constrained geography that is implied, they confirm the importance of inquiring further into the geographic dimensions of the networks established by firms to obtain knowledge.

⁷ Breschi and Lissoni (2001) also argue that technical knowledge is highly specific and its jargon is not that of the broader social community but that of a restricted "epistemic community". Though the latter may be dispersed in space this does not imply any lack of social proximity.

Firm Size, Firm Organization, and Networking

Though the industrial district literature of the 1980s might have implied otherwise, there are now opposed theses about the local networking advantages realized by SMEs. McCann (1995) claims that it is difficult or impossible to demonstrate these advantages while Maskell and Malmberg (1999) argue that learning by SMEs relies on close, local informal interaction. Even keeping the region constant yields equivocal results. The Cambridge region (UK), for example, is claimed to be an innovation node by Aydalot and Keeble (1988) but others (Segal Quince and Partners, 1985; Oakey et al, 1988) point to strong inter-firm relations with other regions and outside the UK. More recent research indicates that a substantial proportion of SMEs network internationally for research, marketing and labour and also achieve high levels of local connection in research (Keeble et al, 1999). In short, there is a high degree of variability in the networks of clustered SMEs. Agglomerations may present no more than the potential for close interaction between firms while other regional advantages such as labour skills, effective relationships with universities, and access to partner firms in other regions may be of real importance (Isaksen, 2001). There are no iron rules.

In advanced technology industries the local or regional mixing of small and large firms has a variety of beneficial possibilities (see above) including faster and more effective diffusion of technical knowledge (Antonelli, 2000). Clearly, the substantial resource strengths of the largest firms make their internal R&D a highly influential component of regional innovation systems. Increasingly, too, large firms enjoy gains from out-sourcing assembly, component design and production, and technical and business services and participation in alliances with other firms in undertaking R&D and product development (Sturgeon, 1997; Howells, 1999a). These shifts towards more highly developed inter-firm network relationships are themselves the result of innovation in the organization of industrial systems, and they make some aspects of the behaviour of large firms more like that of SMEs (see also Ettlinger, 1997). The major difference

is that large firms – especially multinational firms – usually maintain strong intra-corporate connections involving laboratories and plants in addition to external network relationships. Multinational firms according to Pavitt and Patel (1999) concentrate their technological activities especially R&D in their home bases and focus on market adaptation and technical support in host economy locations, though many also take advantage of the technological specializations available in other countries. When they do so they tend to gravitate to the technology core region of the host economy. Maskell and Malmberg (1999) argue that these affiliates can become “insiders” in the regions in which they are invested through long association, or through the acquisition of local firms they can obtain access to regional networks and localized learning in the same manner as smaller firms. Their view, however, is a strongly positive version of the local options that might be exercised by foreign corporations. It certainly is a view that is contrary to the one gained from UK experience (Phelps and Fuller, 2000; Turock, 1993; Munday, Morris, and Wilkinson, 1995). An alternative possibility based more closely on this and Canadian experience (Britton, 1999) is that foreign investment may be more strongly identified as a conduit for the transfer of primary product development undertaken in other corporate locations. Nevertheless, changes in trade and investment regulations through international agreements such as the NAFTA may prompt strategic shifts in the mission of foreign subsidiaries (Britton, 1998).

THE TORONTO CASE

National context – The Canadian industrial economy is highly dependent on international markets and firms in advanced technology industries such as aerospace, have strong inter-regional/international technical relationships with other firms (Anderson, 1995). This is the pattern also for software products, which rely on the U.S. market (Cornish, 1997). A similar international pattern has been found for the strategic technological alliances forged by Canadian firms. Vertical alliances are possible with domestic suppliers but as a small, industrialized

country, Canada offers a limited set of domestic opportunities for horizontal alliances thus encouraging international arrangements (Niosi, 1996; Gertler, Wolfe and Garkut, 1998).

In the aggregate, Canadian advanced technology industries lag the U.S. rate of new product creation because of failures in product conception, design and marketing (Trefler, 1999) and not as a result of low R&D intensities though these do vary between industries and ownership groups. Foreign R&D intensity reaches 27% in Telecommunication equipment compared with 21% for domestic firms while domestic firms record 18% for Other electronic equipment compared with 8.5% for foreign affiliates (Statistics Canada, 1997). The general pattern is that foreign affiliates are firmly enmeshed in the vertically organized structure of their parent firms but at the regional scale research has not yet resolved the functional arrangements adopted by these firms at the establishment level in advanced technology industries. Independent of ownership, there is evidence that small firms in technology intensive industries are more R&D intensive than larger counterparts and it is important to take this company size factor into account also at the regional scale (Gertler, Wolfe and Garkut, 1998; Holbrook and Squires 1996).

Regional Context - Canadian secondary manufacturing activity is concentrated in southern Ontario and when D'Cruz and Rugman (1992) identified regional industrial clusters they separated the advanced manufacturing cluster of Ontario from its auto industry. The current study takes on a finer spatial resolution focusing on Toronto, Ontario's largest manufacturing centre (367,000 employees). It ranks in the middle of the pack of 15 leading high-technology employment centers in North America that have developed information technology specializations PWC (2000)⁸. Using industrial employment location quotients on a similar North

⁸ In the group of 15 metropolitan centres (populations of 3 million or more 1996) Toronto ranked #7 in terms of its 90,000 employment in a broadly defined IT industry. Employment data are based on a telephone survey of establishments each employing 100 or more

American base, Egan (2000) identifies electronics products industries among 10 activities clustered in the Toronto region.

It might seem that the presence in the Toronto region of the headquarters of Nortel Networks and the de Havilland division of Bombardier would define strong corporate leadership in electronics and related industries. Nortel's primary innovation and design centers⁹, however, are located in Ottawa and internationally and the status of de Havilland is an affiliate of a Montreal corporation. Toronto is the home base for several smaller Canadian-owned but internationally competitive domestic electronics firms¹⁰. ATI Technologies and Geac Computer Corporation¹¹ lead but the remaining major Toronto firms¹² have R&D expenditures, in the \$50 million - \$10 million range. Only two foreign electronics companies in Toronto – Ericsson and Motorola - are on the list.

Despite its high North American ranking, Toronto is not viewed as an international "pioneer region" in electronics, has no claim as a neo-Marshallian district and is not a distinct hub-and-spoke type of industrial region as outlined by Markusen (1996). But previous research on SMEs in Toronto has found that their innovation and strong export orientation is sustained by important inputs from producer services. Innovative SME are forward linked to industrial users but this side of their networks is strongly outside Canada, presumably reflecting the limited scale of the

<http://hightech.ebdata.com/>). Metropolitan definitions used are CMAs in Canada and CMSAs in U.S.A.

⁹ Collectively these recorded R&D expenditures of nearly \$6,000 million in 2000.

¹⁰ Canada's "Top 100 Corporate R&D Spenders List" is available from www.researchinfosource.com

¹¹ ATI spent \$224 million on R&D in 2000 and Geac \$120 million.

¹² These include Husky Injection Molding Systems, Celestica, Leitch Technology Corporation, Genesis Microchip, Gennum, Wescam and IMAX.

national market (MacPherson, 1987, 1988). This ties in well with research in Ontario on a broader range of industries that found limited evidence of regional embeddedness compared with an extended spatial dimension to the provincial industrial system (Gertler et al, 2000). Other factors in addition to scale may limit cooperative/collaborative relationships including the competitive and individualistic business culture which may impede firms moving to the leading edge of industrial practice (Gertler et al, 1998). Only further local research focused on high-technology firms in Toronto can resolve whether collaborative activities fall within their common choices.

RESEARCH OBJECTIVES

The kind of learning practices that support the vitality of the electronics cluster in the Toronto region are unclear and this paper explores the interactions of electronics firms with suppliers, customers, collaborators and other members of their knowledge networks. Not only are local connections of unknown strength but also the spatial form of the value chains within electronics remains largely unexplored. Whether the cluster has developed depth in the local interconnection of production activities, producer services, and other knowledge sources is the obvious first question to ask if only because these considerations have been the *sine qua non* of industrial clusters. The firms may be single-plant enterprises, subsidiaries or branch-plants of large companies; regardless, from the regional perspective they are firms and they are the basic units of analysis because they initiate innovation (see below).

I have assumed that Toronto has a highly developed labour market and locational stickiness for the skills needed in the electronics industries. The scale of employment¹³ in these activities

¹³ The 1996 Census of Population for the Toronto CMA shows the manufacturing labour force at 367,000 with 48,000 of that in the electronics cluster; by way of comparison business services are 232,000. Technically the CMA is smaller than the Greater Toronto Area, the study area

makes this reasonable¹⁴. The corollary of these assumptions is that inter-job mobility functions as an important means whereby ideas and knowledge flow within the regional economy. Evidence of other localization or urbanization economies comes from the knowledge networks of firms including connections between them and other kinds of economic agents. These networks involve explicit transfers of knowledge such as might occur through collaboration with other firms in the development of products, inputs from producer service firms such as industrial engineers or designers, and implicit knowledge flows associated with the organization of production systems, involving component suppliers and sub-contractors. These “market” and “collaborative” relationships within firms, between firms and with other kinds of economic actors constitute networks that become apparent when firms for reasons of scale or strategy decide that internal solutions are inadequate or inferior and are not necessarily regionally bounded. In the light of the international literature the goals pursued in this paper are as follows:

1. To assess the strength of the internal compared with external linkages of firms in the cluster with respect to markets, material inputs, and sources of knowledge that might support industrial innovation including alliances. This networks question is designed to confirm the strength and weakness of the internal bonds of the cluster and to identify the complexity of external connections.
2. To evaluate how distinctive foreign electronics affiliates are within the mix of firms in the cluster and to establish whether they differ from the aggregate pattern of foreign affiliates in secondary manufacturing in terms of the strength of their intra-corporate relationships.
3. To establish, independent of ownership factors, whether scale differences between industrial firms have a significant effect on networking choices.

used here, but in practise sample firms have not been drawn from the GTA's eastern extension of the CMA).

¹⁴ Glaeser (2000) supports this aspect of localization economies - “firms locate near other firms that use the same types of workers” (p 84).

Survey Design

In 1998-99, questionnaires were distributed to a sample stratified by ownership of technically similar manufacturing establishments in the electronics industries¹⁵ of the Toronto metropolitan region -- the Greater Toronto Area (see footnote 13). Questionnaires were used because of the quantity of factual data required on the regional and inter-regional connections of establishments. Foreign and domestic lists of relevant establishments were constructed from national R&D web-directories of the National Research Council and Industry Canada, which included the names of contact persons. Each establishment listed as having 100 or more employees was approached¹⁶ by telephone to verify that it was a manufacturer undertaking product development. Foreign affiliates (58) were contacted first yielding a 43% response rate. When 122 domestic establishments were contacted 77% agreed to participate and the response rate for this group was 39% yielding an overall response rate of 41%. Later, using a regional industrial directory (Scott's, 1997), the sample was extended to include smaller firms. Without contact information it was difficult to obtain their cooperation and the response rate for domestic firms declined to 36%.

This sample of 66 respondents is comparable in size with those of Grotz and Braun (1993) and Suarez-Villa and Karlsson (1996) though smaller than the multi-industry Ontario-wide design used by Gertler et al (1998). In terms of response rate the survey compares exceptionally well with others (Suarez-Villa and Walrod 1997) and it achieves representative coverage of the size, and ownership variables and there is no discernable non-response bias in terms of the industry groups from which the firms were drawn (Table 1). In the subsequent survey-based tables,

¹⁵ The industrial scope is similar to that used by Suarez-Villa and Karlsson (1996) and includes Telecommunications equipment, Electronics, Scientific and Professional equipment, and Aerospace.

¹⁶ After an agreement to participate, a questionnaire was mailed usually to the Operations or R&D Manager, or a Vice-President.

respondents that are components of multinational firms are classified in the “large” firm size category. Domestic firms were allocated to two groups – in the “small” size category are SMEs employing fewer than 200 while the “large” domestic establishments employing 200 or more are all members of large corporations operating in other locations in Canada and/or internationally. From the regional perspective, respondents from all groups, for convenience, are often referred to as firms though the differences in their corporate structures are never forgotten.

RESULTS

Are firms in the electronics cluster innovative?

Innovation inputs - It is important to probe how deeply members of the Toronto electronics cluster engage in product development. Differences in their inputs to innovation help identify whether firms are at the leading-edge, where high intensity of Research and Development (R&D) is critical, or whether they are focused on near-market innovation and spend proportionally more on Design and Engineering (D&E). This identification of both R&D and D&E circumvents the limited conception of innovation inputs that are included in R&D. Firms must be able to transform R&D into marketable products and this process requires engineering design – product designers working with manufacturing engineers in the development of products, product lines, and undertaking incremental improvements in products and processes. R&D as used by the federal government for tax credit and related purposes is limited to experimental aspects of product or process development in alignment with the Frascati Manual (OECD, 1994) but as Walsh (1996) points out, this does not cope satisfactorily with design and related inputs.

Many firms do both R&D and D&E. Small highly innovative firms may be focused much more on early phases of product innovation while larger firms, especially market-focused foreign-affiliates with established markets, may require minimal R&D expenditure and be engaged more in product adaptation. The median¹⁷ level of R&D intensity (R&D expenditures / sales) is 3%¹⁸

¹⁷ The (unweighted) median is used because the values are right-skewed.

but foreign affiliates have very low intensity (less than 1%) while for domestic firms it is 5%, verifying a general distinction between these groups. As expected (Holbrook, Squires, 1996), the median for small domestic establishments (5%) is higher than that of large firms (3.5%). Firms responded to a broader definition of innovation inputs in which all R&D+D&E expenditures are included and the median for foreign-owned firms (6.5%) is closer to the domestic level (8%) though the two samples still come from different populations ($p=0.002$)¹⁹. Small firms have even greater R&D+D&E intensities (10%).

The data imply the orientation of many of Toronto's electronics firms to downstream or near-market product innovation, a characteristic that is even stronger for foreign firms. The latter are more focused on undertaking product adaptation for which the basic R&D has been done for home markets such as the U.S.A. It is logical to explore the origins of R&D and D&E inputs (see below) but first it is important to obtain some sense of the innovation outcomes generated by the sample firms.

Innovation Outcomes - Since Canadian firms generally are poor at converting R&D inputs into innovative products it is important to verify that survey firms do produce innovations (Trefler, 1999). On average they recorded what seems to be a modest number of innovations (median=6) over the previous 5 years but there are no well-established norms. I expected a scale effect but there is no relationship between the level of innovation output (number of innovations) and the level of inputs (R&D+D&E employment) because of two small sets of outliers. When the large producers with low-to-modest innovation levels and the very productive small firms with limited numbers of R&D+D&E workers are omitted from the calculations, however, a significant relationship emerges ($r^2 = 0.318$; $p = .000$; Figure 1).

¹⁸ The sample conforms to the high R&D intensity category of OECD.

¹⁹ The Mann-Whitney test is used to compare these two samples.

MARKETS

As a small economy, the truism has been recognized for some time that "virtually all new technology developed in Canada must, directly or indirectly be exported to the US to achieve commercial success" (Steed, 1988). For this reason, it is important to establish the extent to which innovation inputs generate an export capability among Toronto's electronics firms. If this is clear, important clues are obtained about whether innovation inputs are at an effective level. This proposition, in effect, would evaluate for electronics alone using a sample containing all sizes of firms MacPherson's (1987,1988) conclusion for Toronto SMEs that innovation and international export capability are closely interconnected.

Generally, technology intensive firms are expected to have highly focused product and innovation strategies. The logic is that the core competencies of firms – their areas of distinctive expertise - are developed so that they can produce innovative products for specialized markets (Prahalad and Hamel, 1990). For Toronto, many of these markets lie outside both the region and in many cases outside the relatively small-scale Canadian economy and firms predominantly oriented to the domestic market generate a significantly ($p=0.036$) smaller number of product innovations. The export intensities of foreign and domestic firms are at opposite ends of the spectrum with medians of 15% and 75% respectively, and the higher propensity of domestic firms to export is quite clear.

Significantly, neither ownership group finds its major market in the Toronto region. For domestic firms the median share of their sales in this market is 5% and for foreign-affiliates it is 10%. The latter are distinguished by their sales to other Canadian regions and this verifies that as a group they fit within the (Canadian) market-seeking category (Dunning, 1997; Eden, 1994). This ties-in with their relatively stronger D&E compared with R&D. These interpretations raise questions about the way foreign affiliates have responded to the FTA and the NAFTA (Blank and Haar, 1998). The majority has experienced an increase in corporate integration (68%

indicate agreement or strong agreement). Nevertheless, since 1989, foreign affiliates have gained North American or world product mandates.

Models reviewed earlier might lead us to expect that large firms will have a strong export orientation while smaller firms will operate through the regional value chain as contractors. In the Toronto case, however, both small and large domestic firms are weakly committed to the regional market (the medians are 10% and 0.5%). Thus domestic SMEs as a group, have limited forward or downstream connections to other regional firms. They are successful in foreign markets - with a median export intensity of 58% compared with 95% for large domestic firms and 15% for foreign affiliates. This export pattern for SMEs, similar to some high technology European production systems (Grotz and Braun, 1993, 1997; Keeble, Lawson, Lawton Smith et al, 1998), confirms the regional association of innovation and international exports. The absence of major connections by dominant firms within the regional and national markets suggests a poor fit of the Porter model to this cluster. Nevertheless, it is important to evaluate the spatial structure of the input system.

INPUTS

Material inputs - There are many opportunities for backward value chain relationships within the region. Nevertheless, the median proportion of material inputs obtained from the Toronto region is only 25%, verifying that this cluster is strongly reliant on other regions for material inputs and U.S. regions stand out with a median proportion of inputs of 35%. Scale and ownership are important influences as the propensity of establishments to use local sources is related inversely to their scale (log sales) and related directly to domestic ownership ($R^2=0.219$; $p=0.002$). Thus, for small firms the median share of inputs from local suppliers is 50% but only 19% for large firms. This lower propensity to use local inputs is related directly to the flows of highly manufactured sub-systems and sub-assemblies from US corporate sources to foreign affiliates

(Table 2). Corporate imports by foreign-affiliates thus follow a highly selective pattern in which substantial technology content is embodied and transferred.

Much of the literature on industrial districts (see above) leads us to expect that small firms will be more inclined to assemble materials locally while the globalization thesis points to the strong possibility that more specialized inputs for all firms may involve much longer distances. The evidence for Toronto points to SMEs being substantially more dependent on local manufacturers (and distributors), while for large firms (both domestic and foreign) access to international sources of inputs is much more important. Using data on the ranked importance of input origins ranging from the region to larger and distant options (Table 3) the proximity thesis receives limited support because the first or second ranked sources of even basic materials are more often in other parts of Canada or in the U.S.A. This is true, too, for higher value components and sub-systems (Table 3). Embedded within this pattern, U.S. sources are important for foreign affiliates while small domestic firms emphasize local sources for basic (substitutable) materials. But for high value inputs, domestic firms turn strongly to the U.S.A. Many of the region's high technology firms are strongly integrated into the international economy supporting the views of scholars who argue that interregional, and often international, supply connections are the norm for advanced-sector firms in industrial regions (Markusen, 1996; Camagni, 1991; Keeble et al, 1999).

Technical and business knowledge inputs – Many knowledge inputs are arranged directly by (manufacturing) firms with original sources. These “soft” inputs may be generated at any point in the process of industrial innovation whether the goal is new or improved products or production systems. Moreover, the Kline and Rosenberg model indicates that stimuli for innovation potentially come from a variety of sources, all leading to the search for knowledge inputs. Firms may rely exclusively on in-house capabilities and eliminate transaction costs incurred in dealing with other firms, or they may use specialized inputs to complement internal

resources. Consequently, it is important to discover whether electronics firms have established close external working relationships. If these are in place, then the issue is whether they occur in the Toronto region. On the supply-side, the industrial scale and service diversity of Toronto suggests that it may meet many needs of firms (Coffey and Shearmur, 1997). On the demand side, it is necessary to recognize that the various input links that firms organize to access technical and related knowledge are likely to be strongly hierarchical for multi-locational firms. Increasingly, however, firms of all sizes and organizational forms are arranging advanced technical services on a fee for service basis and tap into what is now called the contract research and technology market (Howells, 1999a).

Firms in the Toronto sample provided ordinal data on their most important sources of five knowledge inputs known to be important in the innovation process (Table 4). Three organizational dimensions were examined -- company sources, external sources, and the geography of external sources of knowledge inputs. Strong in-house R&D, and D&E are to be expected as a basic capability for survival, let alone growth, and this is the pattern found for these two key inputs and for (product) testing, and market intelligence (Table 4). Testing is associated with the product design (and certification) process while market intelligence (Cornish, 1997) indicates one way that market responses are assessed. Company sources for software and firmware, however, are weak compared with the other inputs.

Ownership has a perceptibly strong bearing on the sources used for knowledge inputs. For most sampled services, about half of the foreign affiliates gave their first rank reply to the in-house alternative and their second rank response to corporate (USA) sources, a pattern also predominant among large domestic multi-locational firms²⁰. The other foreign affiliates gave first rank responses to corporate sources of knowledge indicating that they have yet to make the

²⁰ This is shown by the high frequencies in the "Other corporate locations" column in Table 5.

full transition to an integrated, specialized mission within their corporations and are still strongly dependent affiliates.

Survey respondents were asked about external sources of knowledge (Table 5). A primary role is often assigned to customers as sources of stimulation for innovations and to distributors as possible parallel sources of market knowledge. Consultants have been included to probe relationships that may deliver expertise from the producer services sector as have partnerships with other firms for product development. The final category includes relationships with units in public institutions, such as universities or colleges. Despite the theorized importance of customers, consultants are the most frequently used channel of knowledge inputs by the sample firms because they have relatively high ratings on all categories of inputs except product testing (Table 5). It is notable that a large proportion of the survey firms uses high order external R&D services, overcoming the transaction costs involved in dealing with a partner or contractor over knowledge-creating activities. Within externally organized R&D and D&E, consultants are responsible for 50% shares of the high order links, shading the importance of other sources such as customers and partners. The consistent significance of consultants among highly ranked sources of knowledge inputs verifies the strong relationship between producer services and advanced manufacturing, and the inter-sectoral basis of the innovation network that supports the cluster.

Flows involving Consultants, Customers, and Distributors - all involve commercial relationships with other firms. By contrast, the channels involving other firms as Partners or Public institutions such as universities are not without financial obligations, but most distinctively involve collaborative methods of working. Partners are the second most frequently cited external source of R&D inputs, D&E, and Product testing verifying the importance of explicitly collaborative components of the innovation process and raising the possibility that relationships associated with learning regions are revealed in the Toronto case. Nevertheless, the survey

shows that Public (including university) sources of inputs are poorly developed and this weakens the inference of advanced forms of collaboration (see below).

The connections of firms with sources outside the region are extensively developed and in aggregate are more numerous than high-ranking knowledge links within the Toronto area (Table 6). Both domestic firms and foreign affiliates establish these external connections, especially with U.S. sources, and there are few major differences in the network connections of different knowledge inputs. The primary exception is the stronger long distance profile of Market Intelligence, which ties in with the international market character of the electronics cluster. The limited high-ranked linkages with Toronto origins appear to stem from the supply side. Other Canadian sources are supplementary sources but even their capabilities or reputations leave firms searching among international locations. The wide array of domestic, North American, and overseas connections that have been accessed is the more impressive.

Collaborative business relationships -

Inter-organizational research and technical cooperation has a long history though its incidence increased in the early 1980s (Howells, 1990, 1999a; Narula and Hagedoorn, 1999).

Agreements take a variety of forms and often are the basis for the development and sharing of compatible knowledge and product systems. While collaboration is easiest for large firms because of their significant human capital, similar relationships have proved to be an option for small firms, too. Limited internal resources give small firms an especially good reason to develop alliances and though the transaction costs may be substantial previous research has shown that small Canadian firms participate (Ahern, 1993). Limited experience and knowledge could favour local alliances but extra-regional collaboration is clearly a source of strength for these firms and would signify a networked region whose firms pull in resources from afar.

I used the survey to inquire further into the importance of alliances as a third type of network component (Grabher, 1993). The data in Table 5 show that 27% of respondents reported that their (established) partners are important sources of a variety of service functions such as R&D, D&E, and Product testing (Table 5). Firms also establish other collaborations; for example, they contribute financial and intellectual resources to projects that the member firms cannot pursue on their own and more than 60% of respondents have some such form of collaboration. Most frequently these alliances are devoted to technology, and product development though production is not too far behind in importance (Table 7); furthermore, more than half the firms with alliances are involved with more than one arrangement. Alliances are, however, mainly an initiative of domestic firms (Table 8) and there are proportionally more among smaller firms ($p=0.024$).

The geographic pattern of alliances is widely dispersed and though predominantly outside the Toronto region (Table 7) domestic firms tend to have Canadian alliance partners ($p=0.02$), a pattern which is influenced by small firms, which have stronger Toronto connections. Conversely, the foreign affiliates that do have alliances tend to search out proportionally more international partners, including some in Europe and the Western Pacific.

Universities and other Public Institutions - In theory, the need to access high-level research expertise drives the connection of firms with universities and other research-based institutions. The relatively low level of R&D compared with D&E by many of the sample firms, however, probably means that they are less likely to seek research partnerships. In the sample, less than one third of respondents are involved with universities and most of these are large domestic firms ($p=0.023$). About half are with institutions in or near Toronto. SMEs are modestly connected with universities though the evidence shows that research intensive SMEs are able to establish R&D or technological knowledge connections with other firms, even internationally. This outcome, which agrees with international research results obtained for small and medium

enterprises (Stokman and Docter, 1987), suggests an institutional divide between small industrial firms and university research facilities – in effect a difference in culture that has not been bridged by effective networking initiatives. Partnerships in research and engineering projects between universities and industrial firms are not a necessary requirement for company or regional success (Maskell and Törnqvist, 1999) but it is important to recognize that universities are sources of tacit knowledge, which is realized most frequently through the regional labour pool.

CONCLUSIONS

The goal of this paper has been to identify the main structural components of the technological networks of Toronto's electronics cluster. This region has an intriguing mix of different types of domestic firms and foreign affiliates and organizational and scale identifiers have proved valuable in understanding the bonds that sustain the cluster. Above all else, the near market orientation of many firms is crucial to understanding the way the bonds of the Toronto electronics cluster are formed -- a number have relatively low R&D intensities though all firms in the survey are innovators.

Foreign affiliates remain more dependent on the R&D and D&E and advanced component resources of other regions than they are on backward links with Toronto's firms. Consequently, they receive the indirect benefit of university and other public and private research connections established by their parent's R&D centers with outcomes embodied in intra-corporate flows of components and producer services. It is easy to view this as a gain for the Toronto region – an example of in-bound technology transfer. This view is problematic, however, because it implies that imports of embodied technology and expertise are always complements to local assets and learning activities. In practice, they may substitute for Toronto-based learning-by-doing in industrial research, product design, and reengineering. Nevertheless, the FTA and the NAFTA

have caused foreign-affiliates to rethink the logic of their Canadian presence. Some have left or opted out of manufacturing but others have become more closely integrated with their parent corporations and compete for corporate-wide functions and new product mandates have been awarded to sample firms. Nevertheless, those that rely heavily on corporate sources of inputs and undertake minimal R&D or D&E in Canada are unlikely to survive the second decade of North American free trade, unless they implement product mandates.

On the whole, domestic firms have a better record of innovation supported by higher R&D intensities. Directly related to this is their export orientation and in this respect free trade has meant an enhanced focus of domestic firms on the US market. Smaller domestic firms as a group are much more innovative and they have an increasing rate of R&D intensity but they have weak downstream connections within the region. Toronto's small electronics firms have developed without substantial market stimulus from large local firms and have positioned their products in international markets though on the input side they rely on local suppliers for about half their material inputs. Large domestic firms, however, source the bulk of their production inputs outside the region. Well-developed material input connections outside the cluster reflect the specialized higher value material inputs needed by firms in the electronics industries. Two factors help to explain the distant-origins of higher-value materials -- first, the cost advantages associated with electronic components from lower-wage economies and/or semi-standardized inputs obtained at attractive prices from international suppliers; second, the international ease with which highly specified inputs may be purchased or production contracts arranged. Viewed in this way the contrast of the global versus the local dimensions of linkage are understandable (Table 9).

The dominant pattern of technical knowledge inputs is one of strong reliance on in-house or corporate resources. This is appropriate, as it is impossible for firms to select among external resources without internal expertise. The pattern of external technical service inputs, however,

is split between Toronto-based connections and those assembled from a wide national and international geography (Table 9). Small firms favour local producer service connections though they cope well with arranging other distant network components. This localized pattern of connections accords with both European results and other North American research and I draw the inference that urbanization and localization agglomeration economies are at work (Bryson and Daniels, 1998; Rusten, 2000; and MacPherson, 1997).

The majority of domestic respondents collaborate with one or more firms from which they secure more specialized and/or advanced knowledge (Table 9). Small firms tend to form alliances within the region or at least in Canada, though this is not true for larger firms. This suggests that close interaction with similar firms, made possible by close geographical proximity, may be an outcome of limited resources and the burden of transaction costs though they are successful in organizing interregional and international sales. Connections with the local tertiary education sector are of modest scale and this fits with the weight given by firms to near-market product design and re-design. It also can be understood in terms of the cultural divide between small firms and universities, or more particularly the limited abilities of small firms to establish or sustain access. This may inhibit development especially when comparisons are made with competitor regions in North America (Egan, 2000; Wolfe, 2002).

Given its mix of domestic and foreign companies, and their well-established international and inter-regional networks, electronics in Toronto is an ideal illustration of the need to view clusters in broad network terms if we are to understand their strengths and possible weaknesses. The results here reveal significant knowledge inputs assembled over long distances, which suggest very strongly that there is an interregional component to the circulation of knowledge in all forms. In addition, to the intra-corporate connections of foreign affiliates, large domestic firms are adept at building long distance, frequently international networks and this active process of knowledge acquisition is an asset-building capability for them and the cluster. Many small firms

also are only modestly embedded in local relationships as they have established major external forward links and have taken advantage of the availability of inter-regional and international sources of specialized inputs when local resources proved inadequate. In short, the version of the cluster concept used here is compatible not only with the realities of globalization but also with the way clusters are enriched by a mix of local and inter-regional networks and learning opportunities. It is sensitive also to the vast differences in the resources of different types of firms.

What are the policy implications?

Both small and large firms are successful at developing geographically complex knowledge networks but appear to do so largely independently of each other. In some jurisdictions this might trigger an increased role for local initiatives designed to enhance local high-value network connections (Maskell, 2001; Economic Development Administration, 1997). These could be directed towards both small firms that have the most limited resources and the weakest knowledge base and to larger firms that may be ignoring local-but-smaller innovators (see Cooke and Wills, 1999). International consultants of the City of Toronto (the core of the region) have followed this approach and a local network forming function runs strongly through their recent recommendations (Egan, 2000). In particular, they argue that there is a need for R&D partnerships between SMEs and universities and suggest that the formation of cluster-based technology networks could provide SMEs with better contractual access to large firms, especially for R&D projects. Regardless, neither the City of Toronto nor the region has an agency that could implement these proposals to enhance local networking. This lack of an effective local organization to assist innovation seems to place Toronto outside the policy mainstream of many industrial regions in other countries but given the analysis here it is difficult to assign great importance to this, at least for the electronics cluster. Moreover, there are small prospects of any organizational changes, which would no doubt require Provincial agreement, to remedy the lack.

On the latter, the two senior levels of government are unlikely to change their style of assisting firms to innovate in any and all locations. They use initiatives ranging from tax credits for R&D expenditures to public-private sector laboratory projects, to a regionally distributed advisory network of the National Research Council that responds to technical requests by firms. Moreover, North American trade liberalization – a national policy initiative - continues to affect Canadian industrial firms and clusters. For electronics in Toronto, for example, the increased acquisition of world and North American product mandates by foreign affiliates, at the very least, will mean an increase in their regional in-house responsibilities. While for SMEs and large domestic firms it seems that before the FTA the modest scale of the Canadian market and the location of major knowledge centres outside Canada induced many in electronics to learn inter-regional and international networking skills. Since then electronics firms have honed these capabilities so that they stand as one of their competitive advantages and a major asset of the electronics cluster and the region.

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REFERENCES

- Ahern R, 1993, "The role of strategic alliances in the international organization of industry" *Environment and Planning A* **25** 1299 - 1246
- Amin A, Robins K, 1990, "The re-emergence of regional economies? The mythical geography of flexible accumulation" *Environment and Planning D* **8** 7-34
- Anderson M, 1995, "The role of collaborative integration in industrial organization: Observations from the Canadian aerospace industry" *Economic Geography* **71** 55-78
- Angel D P, Engstrom J, 1995, "Manufacturing systems and technological change the US personal-computer industry" *Economic Geography* **71** 79-102
- Antonelli C, 2000, "Collective Knowledge Communication and Innovation: The Evidence of Technological Districts" *Regional Studies* **34** 535 - 547
- Arita T, McCann P, 2000, "Industrial alliances and firm location behaviour: some evidence from the US semiconductor industry" *Applied Economics* **32** 1391-1403
- Arundel A, Geuna A, 2001, "Does Proximity Matter for Knowledge Transfer from Public Institutes and Universities to Firms" SPRU, Electronic Working Paper Series, Paper # 73
- Asheim B T, Cooke P, 1999, "Local Learning and Interactive Innovation Networks in a Global Economy" in *Making Connections* Eds E J Malecki, P Oinas (Ashgate, Aldershot)
- Aydalot P, Keeble D (eds), 1988, *High technology industry and innovative environments: the European experience* (Routledge, London)
- Best M H, 199, *The New Competition* (Harvard University Press, Cambridge MA)
- Blank S, Haar J, 1998, *Making NAFTA Work: U.S. firms and the new North American business environment* (University of Miami, North-South Center Press, Miami)
- Bramanti A, Ratti R, 1997, "The Multi-faced Dimensions of Local Development" in *The Dynamics of Innovative Regions* eds R Ratti, A Bramanti, R Gordon (Ashgate, Aldershot) 3-44
- Breschi S, Lissoni F, 2001, "Localised knowledge spillovers vs. innovative milieux: Knowledge "tacitness" reconsidered" *Papers in Regional Science* **80** 255-273
- Britton J N H, 1998, "Is the Impact of the North American Trade Agreements Zero? The Canadian Case" *Canadian Journal of Regional Science* **21** 167 - 196
- Britton J N H, 1999, "Does Nationality Still Matter? The New Competition and the Foreign Ownership Question Revisited," in *The New Industrial Geography* Eds T Barnes, M S Gertler (Routledge, London)
- Brusco S, 1982, "The Emilian Model: Productive Decentralization and Social Integration" *Cambridge Journal of Economics* **6** 167-84
- Bryson J R, Daniels P W, 1998, "Business Link, strong ties, and the walls of silence: small and medium-sized enterprises and external business-service expertise" *Environment and Planning C* **16** 265 - 280
- Carmagni R (ed), 1991, *Innovation networks: spatial perspectives* (Belhaven Press, London)
- Clark G L, 1993, "Global interdependence and regional development: business linkages and corporate governance in a world of financial risk" **18** 309-325
- Coe N M, Townsend A R, 1998, "Debunking the myth of localized agglomerations: the development of a regionalized service economy in South-East England" *Trans. Inst. Br. Geogr* **23** 385-404

- Coffey W J, Shearmur R, 1997, "The growth and location of high order services in the Canadian urban system, 1971-1991" *The Professional Geographer* **49** 404 - 418
- Cooke P, 1998, "Introduction: Origins of the Concept" in *Regional Innovation Systems* Eds H-J Braczyk, P Cooke, M Heidenreich (UCL Press, London)
- Cooke P, 2001, "From Technopoles to Regional Innovation Systems: The Evolution of Localised Technology Development Policy" *Canadian Journal of Regional Science* **24** 21-39
- Cooke P, Wills D, 1999, "Small Firms, Social Capital and the Enhancement of Business Performance Through Innovation Programmes" *Small Business Economics* **13** 219-234
- Cornish S L, 1997, "Product Innovation and the Spatial Dynamics of Market Intelligence: Does Proximity to Markets Matter?" *Economic Geography* **73** 143-165
- D'Cruz J R, Rugman A M, 1992, *New Compacts for Canadian Competitiveness* (Kodak Canada Inc., Toronto)
- DiGiovanna S, 1996, "Industrial Districts and Regional Economic Development: A Regulation Approach" *Regional Studies* **30** 373-386
- Dunning J H, 1997, *Alliance Capitalism and Global Business* (Routledge, London)
- Economic Development Administration, U.S. Department of Commerce, 1997, *Cluster-Based Economic Development* (prepared by Information Design Associates with ICF Kaiser International) Washington D.C.
- Eden L, 1994, "Who Does What after NAFTA? Location Strategies of U.S. Multinationals" in *Multinationals in North America* in L Eden (Ed) (University of Calgary Press, Calgary) pp 193-252
- Edquist C, 1997, *Systems of Innovation - Technologies, Institutions and Organizations* (Pinter, London)
- Egan T, ICF Consulting, 2000, *Toronto Competes: An Assessment of Toronto's Global Competitiveness* (Economic Development Office, Toronto)
- Ettlinger N, 1997, "An assessment of the small-firm debate in the United States" *Environment and Planning A* **29** 419-442
- Feldman M P, 2000, "Location and Innovation: The New Economic Geography of Innovation, Spillovers, and Agglomeration" in *The Oxford Handbook of Economic Geography* eds G L Clark, M P Feldman, M S Gertler (Oxford University Press, Oxford) 373-394
- Feldman M P, 1994, *The Geography of Innovation* (Kluwer Academic Publishers, Boston)
- Florida R, 1995, "Toward the Learning Region" *Futures* **27** 527-36
- Freeman C, 1987, *Technology Policy and Economic Performance – Lessons from Japan* (Pinter, London)
- Freeman C, Perez C, 1988, "Structural Crises of Adjustment, business cycles and investment behaviour", in *Technical Change and Economic Theory* eds G Dosi, C Freeman, R Nelson, G Silverberg, L Soete (Pinter Publishers, London)
- Gardiner P, Rothwell R, 1989, "The strategic Management of Re-innovation" *R&D Management* **19** 147-160
- Gertler M S, 1995, "'Being there': proximity, organization, and culture in the development and adoption of advanced manufacturing technologies" *Economic Geography* **70** 1-26
- Gertler M S, Wolfe D A, Garkut D, 2000, "No Place Like Home? The Embeddedness of Innovation in a Regional Economy" *Review of International Political Economy* **7** 688 - 718

- Gertler M S, Wolfe D A, Garkut D, 1998, "The Dynamics of Regional Innovation in Ontario" in *Local and Regional Systems of Innovation* Eds J de la Mothe, G Paquet (Kluwer Norwell, MA):
- Glaeser E L, 2000, "The New Economics of Urban and Regional Growth" in *The Oxford Handbook of Economic Geography* eds GL Clark, MP Feldman, MS Gertler (Oxford University Press, Oxford) 83-98
- Grabher G, 1993, *The Embedded Firm* (Routledge, London)
- Granovetter M, 1985, "Economic Action and Social Structure: The Problem of Embeddedness" *American Journal of Sociology* **91** 481-510
- Gray M, Golob E, Markusen A, 1996, "Big Firms, Long Arms, Wide Shoulders: The 'Hub-and-Spoke' Industrial District in the Seattle Region" *Regional Studies* **30** 651 - 666
- Grotz R, Braun B, 1993, "Networks, Milieux and Individual Firm Strategies: Empirical Evidence of an Innovative SME Environment" *Geografiska Annaler* **75** B 149 - 162
- 1997 "Territorial or trans-territorial networking: spatial aspects of technology-oriented cooperation within the German mechanical engineering industry" *Regional Studies* **31** 545 - 57.
- Harrison B, Kelley M R, Gant J, 1996, "Innovative firm behavior and local milieu: Exploring the intersection of agglomeration, firm effects, and technological change" *Economic Geography* **72** 233-258
- Henry N, Pinch S, 2000, "Spatialising knowledge: placing the knowledge community of Motor Sport Valley" *Geoforum* **31** 191-208
- Holbrook J A D, Squires R J, 1996, "Firm-level analysis of determinants of Canadian industrial R&D performance" *Science and Public Policy* **23** 369-374
- Howells J, 1990, "The Internationalization of R&D and the Development of Global Research Networks" *Regional Studies* **24** 495 - 512
- 1999a, "Research and Technology Outsourcing" *Technology Analysis and Strategic Management* **11** 17 - 29
- 1999b, "Regional systems of innovation?" in, *Innovation Policy in a Global Economy* Eds D Archibugi, J Howells, J Michie (Cambridge University Press, Cambridge, England, New York)
- Information Design Associates with ICF Kaiser International, 1997, *Cluster-Based Economic Development* (U.S. Department of Commerce, Economic Development Administration, Washington DC)
- Isaksen A, 2001, "Building Regional Innovation Systems: Is Endogenous Industrial Development Possible in a Global Economy" *Canadian Journal of Regional Science* **24** 101-120
- Jaffe A, 1989, "The real effects of academic research" *American Economic Review* **79** 957-970
- Jaffe A, Trajtenberg M, Henderson R, 1993, "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations." *Quarterly Journal of Economics* **108** 577-598
- Keeble D, Lawson C, Moore B, Wilkinson F, 1999, "Collective Learning Processes, Networking and "Institutional Thickness" in the Cambridge Region" *Regional Studies* **33** 319 - 332
- Keeble D, Lawson C, Lawton-Smith H, Moore B, Williamson F, 1998, "Internationalisation Processes, Networking and Local Embeddedness in Technology-Intensive Small Firms" *Small Business Economics* **11** 327-342
- Kline S, Rosenberg N, 1986, "An Overview of the Process of Innovation" in *The Positive Sum Strategy: Harnessing Technology for Economic Growth* Eds R Landau, N Rosenberg. (National Academy Press, Washington, D.C.)

- Larsson S, Malmberg A, 1999, "Innovations, Competitiveness and Local Embeddedness – A study of Machinery Producers in Sweden" *Geografiska Annaler* **81B** 1-18
- Llobrera J T, Meyer D R, Nammacher G, 2000, "Trajectories of Industrial Districts: Impact of Strategic Intervention in Medical Districts" *Economic Geography* **76** 68-98
- Lundvall B-Å, 1988, "Innovation as an interactive process: from user-producer interaction to the national system of innovation" in *Technical Change and Economic Theory* eds G Dosi, C Freeman, R Nelson, G Silverberg, L Soete 349-369 (Pinter Publishers, London)
- Lundvall B-Å (ed), 1992, *National systems of innovation: towards a theory of innovation and interactive learning* (Pinter Publishers London)
- Lundvall B-Å, Johnson B, 1994, "The learning economy" *Journal of Industrial Studies* **1** 23-42
- Lyons D, 1995, "Agglomeration Economies among High Technology Firms in Advanced Production Areas: The Case of Denver/Boulder" *Regional Studies* **29** 265-278
- McCann P, 1995, "Rethinking the economics of location and agglomeration" *Urban Studies* **32** 563-577
- MacPherson A 1987 "Industrial innovation in the small business sector: empirical evidence from metropolitan Toronto" *Environment and Planning A* **20** 953-971
- MacPherson A, 1988, "New product development among small Toronto manufacturers: empirical evidence on the role of new technical service linkages" *Economic Geography* **64** 62-75
- MacPherson A, 1997, "The contribution of external service inputs to the product development efforts of small manufacturing firms" *R&D Management* **27** 127 - 144
- Maillat D, 1991, "The Innovation Process and the Role of the Milieu" in *Regions Reconsidered* eds E Bergman, G Maier, F Tödtling (Mansell, London) 103-117
- Malmberg A, Maskell P, 2002, "The Elusive Concept of Localization Economies. Towards a Knowledge-based Theory of Spatial Clustering" *Environment and Planning A* **34** 429-449
- Manzagol C, 1991, "The rise of a technological complex: some comments on the Phoenix case" in *Industrial change and regional development* eds G Benko, M Dunford (Belhaven Press, London) 237-251
- Markusen A, 1996, "Sticky Places in Slippery Space: A Typology of Industrial Districts" *Economic Geography*, **72** 293 - 313
- Markusen A, Lee Y-S, DiGiovanna S, 1999, *Second Tier Cities -Rapid Growth beyond the Metropolis* (University of Minnesota Press, Minneapolis)
- Maskell P, 2001, "Towards a Knowledge-based Theory of the Geographical Cluster" *Industrial and Corporate Change* **10** 921-943
- Maskell P, Malmberg A, 1999, "The competitiveness of firms and regions: 'ubiquitification' and the importance of localized learning" *European Urban and Regional Studies* **6** 9-25
- Maskell P, Malmberg A, 1999, "Localised Learning and Industrial Competitiveness" *Cambridge Journal of Economics* **23** 167-186
- Maskell P, Törnqvist G, 1999, *Building a Cross-Border Learning Region* (Copenhagen Business School Press, Denmark)
- Morgan K, 1997, "The Learning Region: Institutions, Innovation and Regional Renewal" *Regional Studies* **31** 491-503
- Munday M, Morris J, Wilkinson B, 1995, "Factories or warehouses – a Welsh perspective on Japanese transplant manufacturing" *Regional Studies* **29** 1-17

- Narula R, Hagedoorn J, 1999, "Innovating through strategic alliances: moving towards international partnerships and contractual agreements" *Technovation* **19** 283 - 294.
- Nauwelaers C, Reid A, 1995, "Methodologies for the evaluation of regional innovation potential" *Scientometrics* **34** 497 – 511
- Nelson R R (ed), 1993, *National Innovation Systems* (OUP, New York)
- Niosi J, 1996, "Strategic technological collaboration in Canadian industry: towards a theory of flexible or collective innovation" in *Technological Collaboration* eds R Coombs, A Richards, PP Saviotti, V Walsh (Edward Elgar, Cheltenham) 98-118
- Oakey R, Rothwell R, Cooper S, 1988, *The management of innovation in high-technology small firms: innovation and regional development in Britain and the United States* (Pinter Publishers, London) 1988
- OECD, 2001, *Innovative Clusters – Drivers of National Innovation Systems* (OECD Publications, Paris)
- OECD, 1994, "Main definitions and conventions for the measurement of research and experimental development (R&D) – A summary of the Frascati Manual 1993" (OCDE/GD(94)84, Paris)
- Oinas P, 2000, "Activity-specificity in organizational learning: implications for analyzing the role of proximity" *GeoJournal* **49** 363-372
- Oinas P, Malecki E J, 1999, "Spatial Innovation Systems" in *Making Connections* Eds Malecki E, Oinas P, (Ashgate, Aldershot) 7-33
- Park S O, 1996, "Networks and embeddedness in the dynamic types of new industrial districts" *Progress in Human Geography* **20** 476-493
- Pavitt K, Patel P, 1999, "Global corporations and national systems of innovation: who dominates whom?" in *Innovation Policy in a Global Economy* eds Archibugi D, Howells J, Michie J (Cambridge University Press, Cambridge) 94-119
- Phelps N A, Fuller C, 2000, "Multinationals, intracorporate competition, and regional development" *Economic Geography* **76**: 224-243
- Piore M J, Sable C F, 1984, *The second industrial divide: possibilities for prosperity* (Basic Books, New York)
- Porter M E, 1990, *The Competitive Advantage of Nations* (Free Press, New York)
- Porter M E, 2000, "Location, Competition, and Economic Development: Local Clusters in a Global Economy" *Economic Development Quarterly* **14** 15 - 34
- Prahalad C K., Hamel G, 1990, "The Core Competence of the Corporation" *Harvard Business Review* **68** (May/June) 79 - 91
- PWC (PriceWaterhouseCoopers), 2000, "Comparison of High-Tech Industries in Major North American Metropolitan Area" (Canada)
- Rallet A, Torre A, 1999, "Is geographical proximity necessary in the innovation networks in the era of global economy?" *GeoJournal* **49** 373-380
- Rothwell R, 1986, "Innovation and Re-innovation: A role for the User" *Journal of Marketing Management* **2** 109-203
- Report on Business Magazine, 2001, *The Top 1000* **18** (#1) (*The Globe and Mail*, Toronto)

- Rusten G, 2000, "Geography of outsourcing: business service provisions among firms in Norway" *Tijdschrift voor Economische en Sociale Geografie* **91** 122 - 134.
- Saxenian A, 1994, *Regional Advantage* (Harvard University Press, Cambridge)
- Scott A J, 1988, *New Industrial Spaces: Flexible Production Organization and Regional Development in North America and Europe* (Pion, London)
- 1992, "The Role of Large Producers in Industrial Districts: A case Study of High Technology Systems Houses in Southern California" *Regional Studies* **26** 265-275
- Scott's Directories, 1997, *Ontario Manufacturers* (Toronto)
- Segal, Quince, partners, 1985, *The Cambridge phenomenon: the growth of high technology industry in a university town* (Segal Quince, Cambridge)
- Simmie J, 1998, "Reasons for the Development of 'Islands of Innovation': Evidence from Hertfordshire" *Urban Studies* **35** 1261 - 1289.
- Simmie J, Hart D, 1999, "Innovation Projects and Local Production Networks: A Case Study of Hertfordshire" *European Planning Studies* **7** 445-462
- Staber U 1996 "Accounting for variations in the performance of industrial districts: The case of Baden-Wurttemberg" *Int J Urban Regional Research* **20** 299-316
- Staber U, Morrison C, 2000, "The Empirical Foundations of Industrial District Theory" in *Innovation, Institutions and Territory* eds J A Holbrook, D A Wolfe (McGill-Queen's University Press, Montreal, Kingston) 19-41
- Statistics Canada, 1997, *Industrial Research and Development* Cat # 88-202 XPB (Ottawa)
- Steed G, 1988, "The Canada-U.S. Free Trade Agreement: A Canadian Science and Technology Viewpoint" (Science Council of Canada, Ottawa)
- Stokman C, Docter J, 1987, "Innovation in manufacturing medium-size and small enterprise: knowledge breeds prospects" in *Innovation: Adaptation and Growth* R Rothwell, J Bessant (Elsevier Science Publishers, Amsterdam) 213-236
- Storper M, 1999, "The resurgence of regional economics – Ten years later" in *The New Industrial Geography* Eds T J Barnes, M S Gertler (Routledge, London) 23-53
- Storper M, Scott A J, 1995, "The wealth of regions – Market forces and policy imperatives in local and global context" *Futures* **27** 505 – 526
- Storper M, Christopherson S, 1987, "Flexible specialization and regional industrial agglomerations – the case of the United State motion picture industry" *Ann Assoc Am Geogr* **77** 104-117
- Sturgeon T, 1997, "Turnkey Production Networks in Electronics Manufacturing: A New American Model of Industrial Organization?" University of California - Berkeley, BRIE Working Paper 92A
- Suarez-Villa L, Karlsson C, 1996, "The development of Sweden's R&D-intensive electronics industries: exports, outsourcing, and territorial distribution" *Environment and Planning A* **28** 783-817
- Suarez-Villa L, Walrod W, 1997, "Operational Strategy, R&D and Intra-metropolitan Clustering in a Polycentric Structure: The Advanced Electronics Industries of the Los Angeles Basin" *Urban Studies* **34** 1343-1380
- The Economist* February 9, 2002 "High-tech America - Down in the valley" 54-55; "Boston's high-tech suburbs - Revenge of the brahmins" 55

- Trefler D, 1999, "Does Canada Need a Productivity Budget?' *Policy Options* July-August 66-71
- Turock I, 1993, "Inward Investment and Local Linkages: How Deeply Embedded is 'Silicon Glen'?" *Regional Studies* **27** 401-417
- Von Hippel E, 1994, "Sticky information and the locus of problem solving: implications for innovation" *Management Science* **40** 429-39
- Walsh V, 1996, "Design, innovation and the boundaries of the firm" *Research Policy* **25** 509-529
- Williamson O, 1985, *The Economic Institutions of Capitalism* (The Free Press, New York)
- Wolfe D A, 2002, "Social Capital and Cluster Development in Learning Regions," in *Knowledge, Clusters and Regional Innovation: Economic Development in Canada*, eds J A Holbrook, D A Wolfe (McGill-Queen's University Press, Montreal, Kingston) 11-38
- Wolfe D A, Gertler M S, 1998, "The regional innovation system in Ontario" *Regional Innovation Systems* Eds HJ Braczyk, P Cooke, M Heidenreich: (UCL Press, London) 99 – 135
- Yeung H W, 2000, "Organizing 'the firm' in industrial geography 1: networks, institutions and regional development" *Progress in Human Geography* **24** 301-315

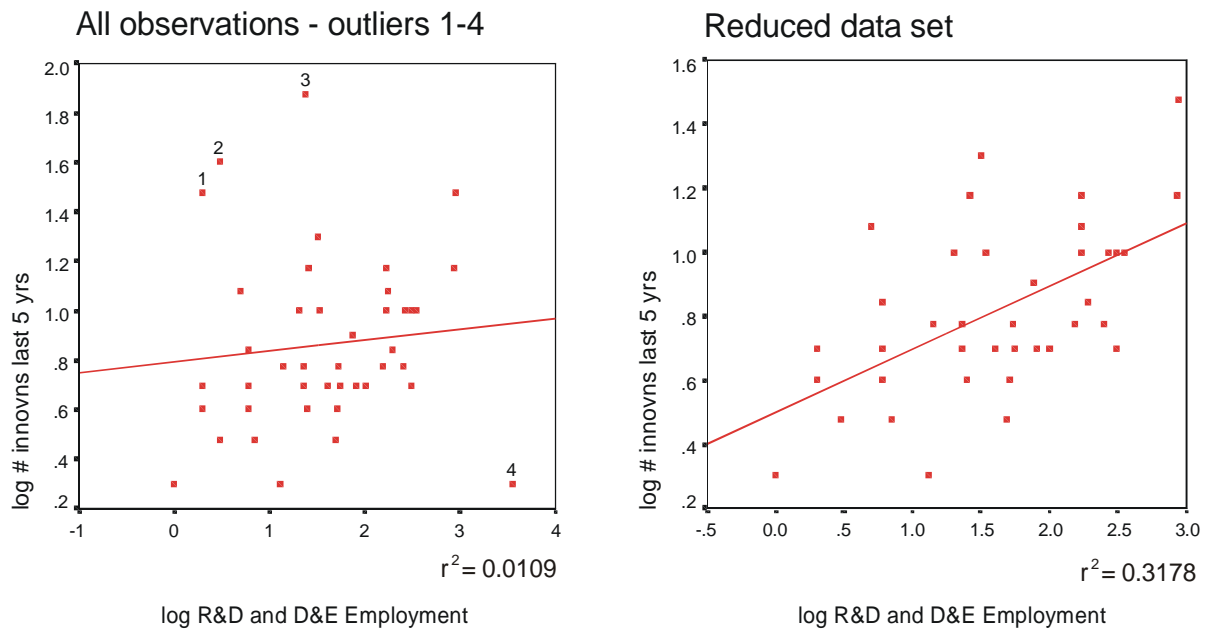


Figure 1: Toronto Electronics Sample: Innovations and Related Employment

Table 1:
Toronto survey: structure

frequencies

Industry group	Foreign Firms	Domestic Firms	Total Sample
Telecommunications	5	13	18
Electronic Parts and components	10	18	28
Aerospace	3	4	7
Scientific and professional equipment	7	6	13
Total	25	41	66

Table 2:
Intra-corporate sources of material inputs

Ownership	Basic materials mean %	Parts & components mean %	Sub systems / sub- assemblies Mean %
Foreign	11.9 (n=14)	20.3 (n=21)	30.3* (n=19)
Domestic	10.0 (n=14)	9.8 (n=16)	4.8* (n=17)
Total	11.0 (n=28)	15.7 (n=37)	18.2 (n=36)

* Significantly different means ($p=0.007$)

**Table 3:
Geographic Origins of Material Inputs**

percentages by row from frequencies

	Toronto	Rest of Ontario	Rest of Canada	U.S.A.	European Union	Western Pacific
Rank 1						
Basic materials	39	9	5	42	3	2
Parts and components	43	10	2	42	0	3
Sub-systems/sub-assemblies	37	12	2	37	2	10
Rank 2						
Basic materials	28	32	6	24	6	4
Parts and components	15	18	13	41	6	7
Sub-systems/sub-assemblies	24	22	8	30	8	8

**Table 4:
Internally Organized (Intra-company) Sources of Knowledge Inputs**

percentages by row from frequencies of ranks 1 and 2 combined*

Knowledge inputs ↓	In-house Toronto Rank 1	In-house Toronto Rank 2	Corporate USA Rank 1	Corporate USA Rank 2	Other Corporate Locations Ranks 1 & 2
	R&D	27	10	10	2
Design and engineering	33	10	9	3	3
Testing	32	11	10	6	2
Software	25	11	6	4	1
Market intelligence	24	11	9	5	5

Note:

*Row frequencies for Tables 5 and 6 have been totalled to calculate percentages.

**Table 5:
Externally Organized Sources of Knowledge Inputs by Supplier**

percentages by row from frequencies for ranks 1 and 2 combined*

Knowledge inputs ↓	Customers	Consultants	Distributors	Partners	Public institutions
R&D	8	21	2	12	3
Design & engineering	8	20	3	8	2
Product testing	15	6	2	12	3
Software	4	37	6	4	1
Market intelligence	19	18	6	2	2

Note:

*Row frequencies for Tables 5 and 6 have been totalled to calculate percentages.

**Table 6:
Externally Organized Sources of Knowledge Inputs by Geographic Origin**

row percentages from frequencies of responses for ranks 1 and 2 combined

	Toronto %	Rest of Ontario %	Rest of Canada %	U.S.A. %	European Union %	Western Pacific %
R&D	46	18	12	19	5	0
Design & engineering	47	25	10	14	2	2
Product Testing	45	16	14	20	4	0
Software	47	18	2	29	4	0
Market Intelligence	44	12	8	25	7	3

**Table 7:
Location of Alliances**

row percentages from frequencies

Type of alliance	Toronto	Rest of Ontario	Rest of Canada	U.S.A.	European Union	Western Pacific
Technology	24	16	17	26	10	7
Product development	21	13	16	29	12	9
Production	28	9	19	20	9	15

**Table 8:
Business Alliances and Ownership of Firm**

frequencies

	Foreign	Domestic	Total
No	14	9	23
Yes	10	31	41
Total	24	40	64

$X^2=8.36$ ($p=0.01$)

**Table 9:
Summary of External Connections**

row percentages from total frequencies

Inputs ↓	from Toronto region	from Other Canadian regions	from International sources
Materials	32	22	46
Knowledge inputs	46	27	27
Alliances	24	30	46