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**Economic Complexity and Industrial Upgrading in the Product Space
Network - Opportunities for the City of Laval, Canada**

Yihan Wang, Assistant Professor,

Department of Strategy and Entrepreneurship

EM Normandie Business School, Métis Lab

yihan.wang@hec.ca

Ekaterina Turkina, Associate Professor,

Department of Entrepreneurship and Innovation

HEC Montréal

ekaterina.turkina@hec.ca

Abstract

This paper studies a city-region's multi-level competitiveness based on the configurations of local product space network and agglomeration of Revealed Competitive Advantage (RCA) sectors. We undertake a mandate studying the economic complexity of the City of Laval and explore the opportunities of industrial upgrading in its product space network. Addressing the importance of subnational analysis of economic complexity, we find the divergence of a city-region's RCA sectors at regional, national and global levels. We also imply the contribution of the structural holes of a city-region's product space network across RCA sectors as potential fields to attract FDI inflow and enhance economic growth. Then, we discover the correlated spatial agglomeration of RCA and structural hole sectors within a city-region's hierarchical ecosystem. Finally, we conclude the practical implications for policy makers and discusses future research directions.

1. Introduction

In the digital revolution, innovation and openness have become the main driving forces of economic growth. Accelerated by technological advances, the industrial upgrading reshape the global competition, that countries with high technological capability and global connectivity takes the lead. To capture the opportunities in the industrial upgrading, national and regional policy makers make effort to attract technology-intensive FDI and enhance local firms' capability of absorbing new knowledge inflows accordingly (Lall, 2000). Synthesizing the arguments on the role of technological innovation and connectivity in globalization, Hidalgo and Hausmann (2009) developed the paradigm of economic complexity and product space network, arguing that the non-tradable capabilities in producing knowledge complex products sustain a country's global competitiveness. In other words, if a country has the competitive advantage specializing in a large variety of technology-intensive industries, its economy has higher growth potential than countries that are only good at a limited number of resource- or labor-intensive industries (Mudambi, 2008). However, this original paradigm of economic complexity and product space network does not take the subnational divergence of regional economic development fully into account. Balland, Rigby, and Boschma (2015) argued that there is an increasing divergence in urban development responding to technological advances and global connectivity. When conducting economic complexity analysis, the subnational divergence in competitiveness, as well as the composition of the city-region product space network into consideration for policymaking (Balland, Boschma, Crespo, & Rigby, 2018; Wang & Turkina, 2019).

This study aims to provide an outlook economic complexity as indicators for global competitiveness of a city-region and to highlight the opportunities in industrial upgrading embedded in the product space network. We elaborate on the contribution of knowledge complexity of competitive manufacturing sectors, the growth potential over the “structural hole” in the product space network, as well as spatial agglomeration of these sectors, as three key elements to understand the opportunities a city-region

achieve competitiveness in industrial upgrading. To demonstrate these points, we undertake a mandate of the Economic Development Service (Service du Développement Économique, SDÉ) of the City of Laval, the third largest municipality in Quebec Province of Canada to understand the city's most competitive manufacturing sectors at regional, provincial and global levels. Thereafter, the municipal economic policy makers can better carry out its investment promotion mission to attract potential international partners and enhance the city-region's position in the global competition.

2. Literature Review

There is a general tendency of innovation-led industrial upgrading towards knowledge-based open economy that reshapes the global competition. Individual economic actors benefit from their connectivity in the hierarchy of network structure, where they can enhance their market performance, innovation capability and social influence (Borgatti & Foster, 2003). In turn, their knowledge creation in the innovation activities embedded in production networks contribute to the regional economic development and global competitiveness (Coe, Hess, Yeung, Dicken, & Henderson, 2004; Cooke & Leydesdorff, 2006; Yeung, 2009). Malecki (1997) urged that the global competitiveness of a country must integrate the economic dynamics and technological capacity at national, regional and local spatial scales. To enhance to the global competitiveness of local firms, national and regional policy makers seek to restructure the local economic development models and industrial policy to generate national competitive advantages. To reach such goals, they are advised to prioritize developing technological sophisticated manufacturing sectors embedded in the networks coordinated by the global value chains (Cano-Kollmann, Cantwell, Hannigan, Mudambi, & Song, 2016; Gereffi, 1999; Gereffi, Humphrey, & Sturgeon, 2005). Hence, the regional specialization and policy perspectives should be taken into consideration to understand industrial upgrading.

The concepts of product space network (Hidalgo et al., 2007) and economic complexity (Hidalgo & Hausmann, 2009) provide a pragmatic analytical framework to tackle the opportunities in industrial upgrading for national states. In general, a country, which takes the lead in producing a broad variety of high technology-intensive manufacturing goods for international trade, is characterized by a high degree of economic complexity. Thereafter, this country has high economic growth potential and takes more favorable position in the global competition (Hidalgo & Hausmann, 2009). In the Atlas of Economic Complexity (Hausmann et al., 2014), the authors analyzed the global trade flows from 1995 to 2017 of more than 1200 types of commodities categorized in the harmonized system (HS) and ranked all nation states and trade commodities by calculating following indicators: *Revealed Comparative Advantage* (RCA), *Diversity Index*, *Ubiquity Index*, *Proximity Index*, and *Product Complexity Index* (PCI)

For a given country c , if the proportion of the export value of product p over the total export value of country c is above the average proportion of total export value product p in global export values, this category of product is recognized as a country's revealed comparative advantage (RCA) sector. Hence, for country c ,

$$RCA_{cp} = \frac{X_{cp} / \sum_{p=1}^n X_{cp}}{\sum_{c=1}^n X_{cp} / \sum_{c=1}^n \sum_{p=1}^n X_{cp}}$$

X_{cp} represents the annual dollar value of product p from country c . If $RCA_{cp} \geq 1$, product p is an RCA sector of country c .

Based on the estimation of the propensity of co-production or co-export of two products, Hidalgo et al. (2007) constructed the framework of product space network of a country. Finally, by weighting the eigenvector value of diversity and ubiquity in recursion expression, Hidalgo and Hausmann (2009) calculated the *Product Complexity Index* (PCI) of each product category. High PCI value indicates the

high knowledge complexity product, while high ECI represent a country's overall competitiveness in the global competition in production and trade.

The economic complexity indices quantify the knowledge intensity of products global competitiveness of countries as reference for international comparison. Understanding the local economic complexity and configurations of the product space network has strong practical implications for economic policy making at multiple levels (Balland et al., 2018). Nonetheless, the general economic complexity and product space network frameworks consider the national context as homogeneous and ignores impact of subnational regional differences (Wang & Turkina, 2019). We call for a more refined view on economic complexity at the city-region level for following reason:

First, the city-region division highlights the increasing subnational regional specialization in networks facilitated by spillover effect. A city-region consists of the urban center (core) and the adjacent suburban territories (periphery) of a municipality. It is the basic spatial unit of large-scale production, and encompasses the economic factors endowment (products, labor, capital, technology), organizational structure and institutional settings embedded in networks (Gibbs & Krueger, 2012; Leibovitz, 2003; Parr, 2005). Within the realm of a city-region, a firm with high capacity in absorbing and proceeding knowledge act as anchor firms to orchestrate knowledge flows local business relationships (Sorenson, Rivkin, & Fleming, 2006). Meanwhile, thanks to the brokerage of the anchor firms, other local firms specialized in the same or related industry get in contact with each other and integrate themselves into the local networks (Arikan, 2009; Fabrizio, 2009; Sturgeon, 2001). In this process, co-located economic players exchange complementary knowledge and generate new ideas based on common knowledge base and mutual trust (Bathelt, Malmberg, & Maskell, 2004; Buckley, Glaister, Klijn, & Tan, 2009; Jaffe, Trajtenberg, & Henderson, 1993; Malmberg & Maskell, 1997). Entailing the spatial, social and institutional proximity of local economic players, such positive spillover contributes to the aggregated specialized knowledge stock and technological capability in the

city-region (Porter, 1998; Feser and Bergman, 2000; Balland *et al.*, 2015). In this sense, the contributions of economic complexity to a country's global competitiveness ultimately reside in the agglomeration of knowledge-intensive industries at the level of city-region (Balland & Rigby, 2017).

Secondly, the core-periphery hierarchy affects the overall competitiveness of city-regions based on the unequal distribution of technological capacity. This system forms as the result of unequal distribution of technology-related factors, including physical plants and facilities, highly skilled human capital, infrastructural connectivity, as well as the institutional support (Porter, 1998; Humphrey and Schmitz, 2002; Lorenzen and Mudambi, 2013). Friedmann (1966) argued that driven by technological advances, the centripetal force of “core” attracts the labor forces and other factors of productions at the “periphery” into the sphere of dominance. As a result, the city-region will reach an equilibrium of interconnection between core and periphery in the process of urbanization (Pain, 2008). Endowed with these favorable conditions, core metropolises are more apt to concentrate strategic resources and attract knowledge intensive FDI and business ventures. In contrast, peripheral suburban or rural regions are more likely to “fall behind” facing stagnation of investment and losing human qualified workforce (Copus, 2001; Felzensztein, Gimmon, & Aqueveque, 2013; Scott & Storper, 2005).

Thirdly, enhancing competitiveness of the city region requires active engagement and coordination of policy makers of multiple levels in the innovation system. An innovation system integrates the roles of firms, governments, communities and many other economic players in a comprehensive socio-technological ecosystem (Lundvall, 1992; Nelson, 1993). In an open innovation system, local firms not only adopt new knowledge from in-house innovation activities, but also absorb external knowledge inflow by interacting with other regional or national economic actors beyond their organizational boundaries (Belussi, Sammarra, & Sedita, 2010; Chesbrough, 2003). Considering the spatial hierarchy, Bathelt and Depner (2003) suggest four perspectives to observe the development of such ecosystem, namely, sectorial, national, regional and metropolitan innovation systems. They argue that in addition

to the self-referential system of individual economic entities, the coordination and support of national or regional institutions also play a crucial role. In other words, well-coordinated institutional support and innovation policy from regional development agencies at multiple administrative levels enhance the regional integration in the national innovation system and ultimately contributes to a country's global competitiveness (Berger, 2008; Gibbs, 2000).

In sum, the subnational divergence of industrial specialization, urban hierarchy and institutional setting all address the importance of understanding economic complexity and product space network from the city-region level. In the empirical analysis, we will use the example of manufacturing sectors of the City of Laval to address these concerns.

3. Product Space Network of the City of Laval

3.1 The City of Laval

The City of Laval (la Ville de Laval) is the third largest municipality in Quebec by population. Located on the north shore of the Saint Lawrence River, the City of Laval is integrated as a subcenter of the Montreal Metropolitan Community (MMC, also known as “Greater Montreal”), the second most populous metropolitan area in Canada after Greater Toronto Area (GTA). The City of Laval was created in 1966 by merging 14 independent municipalities on the Jesus Island (*Île Jésus*) to accommodate the development of urbanization and population spillover in suburban areas in Montreal (Fischler & Wolfe, 2000). The local economy of the City of Laval is well developed and highly diversified. The economic growth of the City of Laval is propelled by knowledge-intensive industries including the life sciences, ICT, agri-food, metal products, machinery and transportation vehicles sectors¹.

¹ Canada Economic Development for Quebec Regions (CED)-Laval: www.dec-ced.gc.ca/eng/regions/laval/index.html

Thanks to its spatial proximity to Montreal, the innovation hub of the Quebec, the city of Laval benefits the positive knowledge spillover effects. Home to the Biotech City (Cité Biotech) and a large number of R&D centers (including a suburban campus of the University of Montreal) and high-tech firms. On the other hand, Laval has lower population density, net rent price, and net absorption/inventory rate than Montreal that encounters the challenges of land scarcity, rising property value, and high costs of demolition. It undertakes multiple commercial and industrial development functions, especially large-scale building projects from Montreal. Meanwhile, the demand for industrial space in Laval is rising as the vacancy rate of real estate occupation sharply drops below the average of the Greater Montreal Area.

As the municipal policy maker of regional economic development, the City of Laval Economic Development Service (Service du Développement économique de Ville de Laval, SDÉ) offers support to the business development of local firms, attracts potential investors, and coordinates inter-organizational relationships on its territory². SDÉ has already identified life sciences, aeronautics and food processing industries as the city's strategic sector to sustain economic growth. According to the industrial agglomeration tendency of manufacturing subsectors, SDÉ divides the industrial development into west, central and east divisions along the Highway 440. Meanwhile, SDÉ aims to identify other crucial manufacturing sectors that support the growth of existing strategic industries as well as sustain the connectivity of local business networks by analyzing the local product space network configurations. Following this mandate, the research aims to use the analytical techniques of economic complexity and product space network to identify the most competitive economic sector, then compare to regional (provincial), national and global benchmark. Moreover, we explore the structural holes of the RCA sectors embedded in the product space network as potential areas to attract

² The City of Laval Economic Development Service (in French): lavaleconomique.com

FDI. Then we depict the geographic features of RCA sector agglomerations and structural holes in the product space network.

3.2 Data Collection and Product Space Network Construction

Following the paradigm of economic complexity and product space network (See Appendix), we collected the municipal-level data of the City of Laval and incorporate the available data in the analytical framework. We first track to the dyadic linkages between four-digit harmonized system 1992 standard (HS92) provided by *the Atlas of Economic Complexity* (Simoes & Hidalgo, 2011), and build up the inter-sectorial product space network framework accordingly. Then, we also calculate the 6-year average PCI index of each HS92 product category from 2012 to 2017 as measurement for the knowledge complexity of production activities. If the average PCI is positive, we note the manufacturing sector producing this product as high-PCI sector, *vice versa*.

Next, we match the trade data provided by regional (Institut de la statistique du Québec), national (Statistics Canada), and global (UN Comtrade Database) statistics authorities with the distribution of economic sectors embedded in the product space network. To acquire municipal data of the City of Laval, we record valid registration information of operating enterprises in 2019 located in the City of Laval from the provincial manufacturing datasets provided by Banque d'information industrielle of the Centre de recherche industrielle du Québec (CRIQ) and Registraire des entreprises du Québec (REQ). The municipal dataset includes name of the enterprise, Quebec enterprise number (le numéro d'entreprise du Québec, NEQ), industrial sector (North American Industry Classification System (NAICS) Canada 2017), location (postal code), number of employees, year of foundation, and revenue.

After that, we integrate available corporate data to the municipal-level product space network framework. First of all, since the product space network mostly focus on good production, we only include firms specialized in agriculture (NAICS 11), mining (NAICS 21) and manufacturing (NAICS

31-33) sectors by referring to the first two digits of their main industrial categories. Since the NAICS code identifies the main economic activities a firm is specialized in, whereas the HS code register the main type of final product a firm prepares to export, we conducted concordance between the registration of NAICS 6-digit codes with HS 4-digit codes by keyword matching (Pierce & Schott, 2012).

Since a large majority of local enterprises in the City of Laval do not engage in export activities, instead of referring to trade data, we calculate the municipal level RCA index by referring to the number of employment in each economic sector over the total number of employed population. This adjustment combined with the calculation of the Location Quotient (LQ), a broadly applied method to identify industrial agglomeration by comparing the regional employment in each manufacturing sector overall national average (Delgado, Porter, & Stern, 2010; Resbeut & Gugler, 2016; Turkina & Van Assche, 2018). Since high degree of LQ is strongly correlated with the trade volume of the final products of each economic sector (Chiang, 2009; LeSage, 1990), we calculate the adjusted RCA of a municipality as follows:

Suppose export value of industry i in municipality m is a return-to-scale constant function of employment of industry i in municipality m , that is,

$$X_{im} = f(E_{im}) = E_{im} \times C,$$

therefore,

$$LQ_{im} = \frac{E_{im}/E_m}{E_{in}/E_n} \Rightarrow E_{im}/E_m = LQ_{im} \times (E_{in}/E_n)$$

$$RCA_{im} = \frac{X_{im}/X_m}{X_{ig}/X_g} = \frac{f(E_{im})/f(E_m)}{X_{ig}/X_g} = \frac{E_{im}/E_m}{X_{ig}/X_g}$$

E : Employment; X : Value of exports; i : category of goods; m : municipality; n : national average; g : global average; C is a constant.

After these concordance and adjustment processes, we calculate the RCA indices of all good producing sectors of the City of Laval by comparing municipal employment proportion by sector to world average trade value by sector (2017). The layout of the product space network of the City of Laval is displayed as Figure 9. The node size represents the number of employees in each manufacturing sector, and the node colors represents the degree of complexity of RCA sectors.

[Figure 1 here]

4. Industrial Competitiveness in the Product Space Network

To identify the industrial competitiveness of the City of Laval, we calculate the RCA indices (RCA World³) of good producing sectors and compare their PCI indices. Among 1224 manufacturing sectors included in the original Product Space Network, enterprises in the City of Laval conduct production activities in 132 sectors. There are in total 55 RCA sectors by world standard, which count for 41.7% of all local manufacturing sectors. More than half of local manufacturing sectors are of high-PCI ($N=73$, $p=55.3\%$). The percentage of RCA sectors of high PCI of the city of Laval ($N=35$, $p=63.64\%$) is higher than the same ratio of Quebec ($p=52.49\%$) and of Canada ($p=50.75\%$) (Wang & Turkina, 2019).

The leading employment sectors are mostly concentrated in life sciences (special pharmaceuticals, medical instruments), aerospace industry (aircraft parts), food processing industries (pig meat, baked goods), which align with the strategic sectors identified by SDÉ (See Table 1). Meanwhile, specialized papermaking (newsprint), housewares (bell and other metal ornaments, furniture), and machinery and transportation vehicles (iron structures, vehicle bodies, interchangeable tool parts, lifting machinery,

³ Unless specified, the RCA indices represent the ratio local employment rate of this manufacturing sector over the world average value of export goods of the same sector.

construction vehicles, vehicle parts) sectors also attract large amount of employment. Among these leading manufacturing sectors in terms of employment, the main global competitors are the exporters from Germany and China. On the other hand, the USA, the largest trade partner of Canada and Quebec (Wang & Turkina, 2019), serves as the largest import market for many local firms of the City of Laval. In this sense, the City of Laval can take the advantage of geographic proximity and existing free trade agreement (FTA) in the USA over other global competitors from Asia-Pacific and Europe.

[Table 1 here]

Notwithstanding, re-ranking the manufacturing sectors by RCA indices, we find out that the most competitive manufacturing sectors of the City of Laval exceed beyond the 3 strategic industries of the City of Laval (See Table 2), including housewares (bell and other metal ornaments), specialized papermaking (newsprint, other carbon paper), textiles (gum coated textile fabric, knit clothing accessories), machinery and transportation vehicles (metalworking machines, traffic signals, vehicle bodies, other construction vehicles) and chemicals (soap, scrap plastic). Though aircraft parts sector is still an RCA sector (RCA Index= 1.827), its competitiveness is not as evident as many other sectors. From the geographic perspectives, the distribution of competitors and partners turns out to be more versatile. On the one hand, similar to main employment sectors, exporters from Germany and China are the major global competitors of RCA sectors, while the USA is the main export market. On the other hand, the competition from other emerging economies (e.g. Thailand, Turkey, Indonesia) also challenges the global competitiveness of local firms of Laval, whereas Japan and EU countries (France and the Netherlands) emerge as potential destinations to form collaboration. Interestingly, there are also sectors the location of main competitors and partners swap the position. For example, the world's largest export of scrap plastic is the USA while the largest importer is China. Given Laval's competitiveness in the sector (RCA =5.658, PCI=-0.891), local plastic manufacturers should be aware

of the high competition in the US market meanwhile consider forming supply chain partnership with customers in China.

[Table 2 here]

Replacing the denominator of RCA to X_{ig}/X_g (the world's average value of exporting goods of manufacturing sector i over total exporting goods value), to the same ratio of export value by sector in Quebec (X_{ir}/X_r) and Canada (X_{in}/X_n), we can also calculate the RCA indices of Laval's manufacturing sectors over regional (RCA Quebec) and national (RCA Canada) average. The regional, national and global competitiveness are not always in coherent with each other. We find out that, for some industries, the City of Laval has even higher competitiveness in the regional or national market than in the global market (e.g. bells and other metal ornaments (HS8306, PCI=-0.866): $RCA_{World}=54.137$, $RCA_{Canada}=123.031$, $RCA_{Quebec}=331.988$; special pharmaceuticals (HS3006, PCI=1.087): $RCA_{World}=22.524$, $RCA_{Canada}=45.639$, $RCA_{Quebec}=23573.010$); other metal fasteners (HS8308, PCI=0.392): $RCA_{World}=18.11$, $RCA_{Canada}=442.43$, $RCA_{Quebec}=107.042$. Moreover, there are industries that do not have global competitiveness but rather local competitiveness (e.g. air pumps (HS8414, PCI=1.543): $RCA_{World}=0.413$, $RCA_{Canada}=1.223$, $RCA_{Quebec}=1.302$). Hence, local firms specialized in these industries should prioritize exploiting existing domestic market exploring the global market. In contrast, some other manufacturing sectors are more competitive in the global market than in the domestic market (See Table 3 and Table 4). For example, the City of Laval has global competitiveness in large iron containers (HS7309, PCI=0.111) sector ($RCA_{World}=1.364$), but neither regional nor national competitiveness ($RCA_{Canada}=0.980$, $RCA_{Quebec}=0.573$). Hence, firms specialized in these manufacturing sectors have higher potential exploring the global market to offset the high competition in the domestic market. Therefore, we suggest diversified competitive strategies in the

domestic and global markets. Local firms should consider coordinate their competitive relations with counterparts in other city- regions in Quebec and Canada.

[Table 3 here]

[Table 4 here]

5. Structural Holes in the Product Space Network

Our next step is to identify the structural holes in the product space network of the City of Laval. The structural holes represent the separation between non-redundant contacts in a social network (Burt, 1992). In other words, adding a “common third party” bridging the structural holes between two unconnected network players facilitates the knowledge flows and new opportunity exploration, thereafter, enhances the overall network connectivity and structural cohesion (Gargiulo & Benassi, 2000).

In this study, we look into the ego networks of RCA sectors, that is the whole body of the alter nodes of an ego node has direct connection with, as well as the linkages between them (Everett & Borgatti, 2005). Hence, the adjacent non-RCA in the ego networks of RCA sectors are regarded as structural holes in the product space network. Hidalgo et al. (2007) argued that a direct linkage between two manufacturing sectors in the product space network represents the complementary capability a region can produce and export products of both sectors. In this sense, a structural hole between RCA sectors and non-RCA sectors indicate a potential field of growth, since local firms specialized in the structural hole sectors benefits from knowledge sharing of other firms specialized in RCA sectors based on cognitive, social and geographic proximity (Boschma, 2005). In addition, bridging the structural hole between RCA sectors and non-RCA sectors enhances the overall connectedness and cohesion of local

product space network, which, in turn, contributes to economic complexity and growth potential of the region (Hidalgo & Hausmann, 2009).

To identify the structural holes, we segregate all RCA sectors in a separate network and reach their first-degree ego networks of direct connects (See Figure 2). From the first-degree ego network of RCA Sectors of the City of Laval, we can, first of all, observe a clear core-periphery structure. At the center of this network, there is a densely connected giant component that mixes both RCA and non-RCA sectors. At the network core, there are strong clustering tendencies in machinery, construction, food processing and textiles industrial of RCA sectors surrounded by a large number of non-RCA sectors in the structural holes. On the other hand, strategic manufacturing sectors such as life sciences and aerospace industries lack dense connections to other RCA sectors via the bridges over structural holes. At the network peripheral, we can also observe a few isolates without connection to the giant core. Some of these isolates even turn out to be RCA sectors with a large amount of employment such as aircraft parts, bells and other metal ornaments, other construction vehicles. Such results indicate that the intra-regional coordination of these peripheral sectors is not as sufficient as core sectors. Thereafter, filling the structural holes by either incubating scale-up of local firms or attracting FDI from countries that has global competitiveness in these complementary structural hole sectors of local RCA sectors.

[Figure 2 here]

Finally, we rank the PCI of all non-RCA sectors of the City of Laval and selected those of high PCI (See Table 5). These industries are those with the closest knowledge proximity to existing RCA sectors in the City of Laval, and of high growth potential. Most of these industries are concentrated in machinery and transportation vehicles, chemicals, housewares and textile sectors, which are all among the three strategic sectors. Regard to the global competition, we discover that, the most competitive economies of these high-PCI structural hole sectors are either in China or Germany, while the USA is

the world's largest importer of these products. Therefore, the City of Laval can consider strengthening attraction of FDI from China and Germany, while continue exploring and exploring the final product market in the nearby US market.

[Table 5 here]

6. Local Clustering in the Product Space Network

In this section, we detect the agglomeration tendency of RCA sectors and structural hole sectors in municipal districts of the city of Laval. We refer to the first 3 digits of postal code of a firm's registration location in the CRIQ and REQ datasets, then assort employment and industrial categories (HS codes and NAICS codes) by district. Then we count the number of RCA sectors (regional/national/global), high-PCI sectors, and structural hole sectors (See Table 6).

[Table 6 here]

Aligning the strategic outlook of SDÉ, the large majority of employment in manufacturing sectors are located in the three industrial divisions - Central (Sainte-Rose, Chomedey Nord-est, Chomedey Est, Chomedey Nord-ouest), East (Saint-Vincent-de-Paul, Duvernay), and West (Fabreville). Among all municipal districts, Sainte-Rose district attract most of the employment and firms specialized in high-PCI sectors, RCA sectors and structural hole sectors. Located to the north of 440 Highway, Sainte-Rose District is located next to Chomedey District, the administrative center of the City of Laval, but exceeds the latter in all aforementioned indicators. Meanwhile, both districts are positioned in the central industrial hub of the City of Laval, counting for 71.93% of the total employment of the city. Therefore, within the city-region of the City of Laval, there is a clear core-periphery distribution of manufacturing sectors. Meanwhile, East Division (Saint-Vincent-de-Paul, Duvernay) and West Division (Fabreville) also attract substantial number of manufacturing firms and absorb the population

spillover from Central Division of the City of Laval, as well as from the nearby metropolis Montreal (See Figure 3). Hence, in the City of Laval, there is the anchoring effect of functions diffusion from the core to the periphery (Friedmann, 1966).

[Figure 3 here]

Meanwhile, we observe the high correlation of a number of RCA sectors, high-PCI sectors and structural hole sectors among municipal districts (See Figure 4). Most of these sectors are agglomerated in Sainte-Rose District, followed by Chomedey, Saint-Vincent-de-Paul, Fabreville, and Duvernay. These districts have higher national and global competitiveness than regional competitiveness. Considering the high local competition of many strategic manufacturing sectors in Quebec (e.g. aircraft parts, newsprint, meat processing, machinery), outgoing strategies exploring new opportunities in the national or international market can enhance the overall competitiveness of local industries. Finally, we also observe the concentration tendency of structural hole industries in Central Division (Sainte-Rose and Chomedey) of the City of Laval. Hence, this central industrial hub serves the role as the coordinators of knowledge flows between firms specialized in RCA sectors as well as the most potential area to attract FDI from countries of global competitiveness in these sectors.

[Figure 4 here]

7. Conclusions and Discussions

This research demonstrates the mechanisms how city-regions can capture opportunities in industrial upgrading and achieve global competitiveness. Such goal can be achieved by developing knowledge-intensive advantageous sectors and enhancing the connectivity with global leaders in closely related industries. To elaborate these points, we apply the paradigm of economic complexity and product space network to identify the high-PCI RCA sectors and the structural sectors of the City of Laval. This study

integrates multiple levels of a city-region's industrial competence - sectorial diversification, knowledge intensiveness, labor force specialization, spatial agglomeration and inter-sectorial connectivity. Characterized by high degree of industrial diversification and strong competence in knowledge-intensive sectors, the economy of the City of Laval not only benefits from the spillover effect from the nearby metropolis Montreal, but also incubates a complete and independent micro-ecosystem integrating local firms, employees and governmental authorities. Overall, this study is a pioneer research on the economic complexity and product space network at the city-region level and has strong practical implication for regional industrial policy addressing the regional, national and global layers of a city-region's global competitiveness. In this research, we claim the contributions as follows:

First and foremost, we address the importance of city-region level analysis of economic complexity for the local and global competitiveness as well as the policy implications. By applying adjusted RCA analysis, we analyze the regional, national and global competitiveness of manufacturing sectors of the City of Laval. Moreover, the RCA sectors of the City turn out to be of high degree of versatility from following perspectives. From the aspect of economic complexity, high-PCI sectors count as the majority of all RCA sectors of the City of Laval. Their proportion over all RCA sectors at the municipal-level weights higher than the regional and national average. Hence, the local policy makers should also be aware of the “potential champions” of high-PCI RCA sectors in addition to the strategic sectors already identified. For low-PCI RCA sectors, though they may not directly serve as local economic growth engine, they may still play crucial roles in local employment and bridge the connectivity between high-PCI RCA sectors in the product space network.

Secondly, we introduce the concept of the structural hole in the framework of product space network and argue that first-degree non-RCA connections of the RCA sectors bridge these structural holes for intersectoral knowledge flows. Specifically, structural hole sectors with high PCI serve as the potential

fields of industrial upgrading and economic growth. Therefore, the policy makers should also be aware of their growth potential and attract FDI accordingly.

Finally, we detected the tendency of spatial agglomeration of manufacturing sectors in municipal districts. We clearly illustrate the core-periphery of hierarchical urban systems of the City of Laval, which is independent from the nearby metropolis Montreal. Moreover, there is a strong correlated tendency between the number of firms specialized in RCA sectors and those specialized in high PCI sectors and structural hole sectors. In this process, whereas coordination with neighbouring city-regions is important for the urban development, the policy making of the City of Laval can take more autonomy by orchestrating the industrial structure in its own urban system.

Though we made our best efforts to accomplish the mandate, due to the constraints of the analytical framework and data availability, there are still numerous limitations of the research leaving open questions for further exploration. We suggest exploring how the configurations of the municipal product space networks contribute to the innovation capability of local manufacturing firms at the micro-level. From spatial perspective, we can compare the intra-municipal industrial transfer from the core to peripheral with the inter-municipal spillover over from the metropolis to the adjacent suburban areas. From chronological perspective, the timeline of local firm establishment as well as the growth of industrial clusters can also be a direction to understand the processes of industrial upgrading. In all, economic complexity and product space network provide practitioners and policy makers with highly applicable tools to identify their strategic goals, competitiveness, and potential for future development of city-regions.

Tables

Table 1: Top 15 Employment Manufacturing Sectors of the City of Laval

Ran k	SH Code	Product	PCI	Employment	RCA World	Top Exporter	Top Importer
1	3006	Special Pharmaceuticals	1.087	1956	22.524	Germany	USA
2	8803	Aircraft Parts	0.641	974	1.827	USA	USA
3	4801	Newsprint	0.903	951	35.432	Canada	USA
4	203	Pig Meat	0.829	873	4.830	Germany	Japan
5	1905	Baked Goods	-0.346	821	4.084	Germany	USA
6	8306	Bells and Other Metal Ornaments	-0.866	691	54.137	China	USA
7	9018	Medical Instruments	0.225	551	0.782	USA	USA
8	9403	Other Furniture	0.880	551	1.088	China	USA
9	7308	Iron Structures	0.442	535	1.864	China	Norway
10	8707	Vehicle Bodies	1.301	461	9.560	Germany	the Netherlands
11	8207	Interchangeable Tool Parts	1.354	437	3.210	Germany	Germany
12	3401	Soap	-1.234	426	6.627	Indonesia	USA
13	8428	Lifting Machinery	1.161	411	2.361	China	USA
14	8430	Other Construction Vehicles	-0.288	386	7.001	China	USA
15	8708	Vehicle Parts	1.202	346	0.148	Germany	USA

Table 2: Top 15 Manufacturing Sectors with Highest RCA of the City of Laval

Rank	SH Code	Product	PCI	Employment	RCA World	RCA Quebec	RCA Canada	Top Exporter	Top Importer
1	8306	Bells and Other Metal Ornaments	-0.866	691	54.137	311.988	123.0312	China	USA
2	4801	Newsprint	0.903	951	35.432	0.597368	2.485388	Canada	USA
3	4816	Other Carbon Paper	0.025	77	25.434	944.7565	326.0578	Thailand	Japan
4	3006	Special Pharmaceuticals	1.087	1956	22.524	23573.01	45.63924	Germany	USA
5	2001	Pickled Foods	-0.762	231	19.225	31.20773	151.758	Turkey	USA
6	5901	Gum Coated Textile Fabric	-0.476	54	18.111	107.0423	442.4261	China	USA
7	8308	Other Metal Fasteners	0.392	334	16.036	198.4054	114.6668	China	France
8	8461	Metalworking Machines	1.676	200	14.202	45.82016	33.67782	Germany	China
9	8530	Traffic Signals	0.867	149	9.723	5.196481	8.460441	Germany	USA
10	8707	Vehicle Bodies	1.301	461	9.56	5.32627	5.590991	Germany	the Netherlands
11	9402	Medical Furniture	0.777	196	8.878	N/A	N/A	China	USA
12	8430	Other Construction Vehicles	-0.288	386	7.001	5.084189	6.269892	China	USA
13	3401	Soap	-1.234	426	6.627	2.993684	5.387762	Indonesia	USA
14	6117	Other Knit Clothing Accessories	-1.247	107	5.696	15.50642	40.42998	China	USA
15	3915	Scrap Plastic	-0.891	164	5.658	4.554533	7.049571	USA	China

Table 3: List of Manufacturing sectors Low Regional Competitiveness and High Global Competitiveness

(RCA Quebec<1, RCA World>1)

HS Code	Product	Employment	PCI	RCA Quebec	RCA Canada	RCA World	Top Exporter	Top Importer
8803	Aircraft Parts	974	0.641	0.799	1.242	1.827	USA	USA
4801	Newsprint	951	0.903	0.597	2.485	35.432	Canada	USA
203	Pig Meat	873	0.829	0.507	1.381	4.830	Germany	Japan
7308	Iron Structures	535	0.442	0.750	1.870	1.864	China	Norway
8428	Lifting Machinery	411	1.161	0.960	1.672	2.361	China	USA
2106	Other Edible Preparations	309	0.147	0.816	1.246	1.320	USA	UK
4818	Toilet Paper	75	0.166	0.183	0.586	1.156	China	USA
4408	Veneer Sheets	60	-0.708	0.451	0.812	3.180	China	India
7309	Large Iron Containers	30	0.111	0.573	0.980	1.364	China	USA

Table 4: List of Manufacturing sectors Low Regional Competitiveness and High National Competitiveness

(RCA Quebec<1, RCA Canada>1)

HS Code	Product	Employment	PCI	RCA Quebec	RCA Canada	RCA World	Top Exporter	Top Importer
8803	Aircraft Parts	974	0.641	0.799	1.242	1.827	USA	USA
4801	Newsprint	951	0.903	0.597	2.485	35.432	Canada	USA
203	Pig Meat	873	0.829	0.507	1.381	4.830	Germany	Japan
7308	Iron Structures	535	0.442	0.750	1.870	1.864	China	Norway
8428	Lifting Machinery	411	1.161	0.960	1.672	2.361	China	USA
2106	Other Edible Preparations	309	0.147	0.816	1.246	1.320	USA	UK
8529	Broadcasting Accessories	201	0.569	0.819	1.609	0.522	China	China
3903	Styrene Polymers	115	1.022	0.573	3.212	0.845	South Korea	China
4009	Rubber Pipes	60	1.084	0.572	2.075	0.989	Germany	USA
6203	Non-Knit Men's Suits	60	- 1.321	0.260	1.247	0.205	China	USA
207	Poultry Meat	58	0.227	0.396	1.139	0.374	Brazil	Germany
2204	Wine	19	- 0.543	0.439	1.116	0.090	France	USA
8408	Combustion Engines	17	1.537	0.564	1.014	0.059	USA	USA
4303	Furskin Apparel	5	- 0.335	0.312	1.172	0.175	China	Russia

Table 5: Structural Hole Sectors of Positive PCI

SH Code	Product	Employment	PCI	RCA_World	Top Exporter	Top Importer
8414	Air Pumps	176	1.543	0.413	China	USA
8481	Valves	85	1.485	0.164	China	USA
8419	Other Heating Machinery	153	1.322	0.665	Germany	USA
8708	Vehicle Parts	346	1.202	0.148	Germany	USA
8538	Electrical Power Accessories	50	1.178	0.232	Germany	China
3909	Amino-resins	44	1.176	0.422	Germany	China
5903	Plastic Coated Textile Fabric	29	1.085	0.364	China	USA
4009	Rubber Pipes	60	1.084	0.989	Germany	USA
9405	Light Fixtures	79	1.040	0.254	China	USA
7326	Other Iron Products	140	0.996	0.498	China	USA
4016	Other Rubber Products	106	0.889	0.679	Germany	USA
5603	Non-woven Textiles	36	0.863	0.396	China	USA
8302	Metal Mountings	3	0.848	0.016	China	USA
7019	Glass Fibers	10	0.769	0.138	China	Germany
8501	Electric Motors	68	0.736	0.217	China	USA
8418	Refrigerators	47	0.616	0.183	China	USA
3920	Raw Plastic Sheeting	270	0.374	0.808	Germany	China
1806	Chocolate	14	0.238	0.084	Germany	USA
9401	Seats	12	0.172	0.026	China	USA
5801	Woven Fabrics	11	0.050	0.863	China	UK
4411	Wood Fiberboard	7	0.037	0.118	Germany	USA

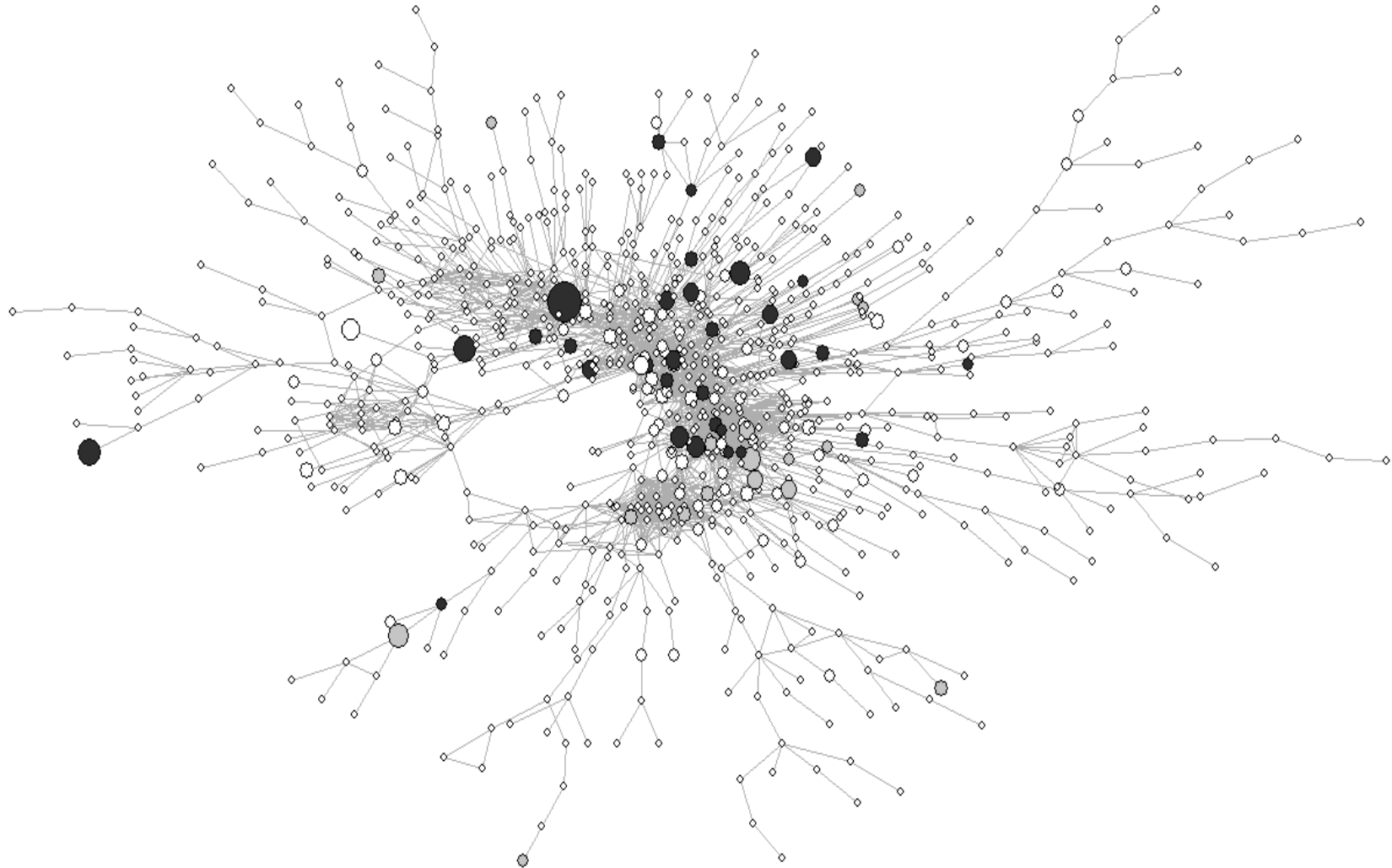
Table 6: Manufacturing sectors in Municipal Districts of the City of Laval

Ran k	District	Posta l code	Employmen t	High PCI	RCA Quebe c	RCA Canada	RCA World	Structura l Holes
1	Sainte-Rose	H7L	8908	160	105	153	149	26
	Chomedey*		5377	88	59	81	75	18
2	Chomedey Nord- est	H7S	2875	47	24	35	36	11
3	Saint-Vincent-de- Paul	H7C	2274	40	26	37	38	6
4	Chomedey Est	H7V	1361	19	16	21	16	4
5	Fabreville	H7P	982	30	28	34	33	6
6	Duvernay	H7E	684	14	22	22	22	6
7	Chomedey Nord- ouest	H7T	656	15	16	17	14	2
8	Vimont	H7M	583	14	14	16	16	7
9	Chomedey Sud	H7W	485	7	3	8	9	1
10	Pont-Viau	H7G	300	9	7	9	9	3
11	Saint-François	H7B	158	4	4	5	6	0
12	Laval-sur-le-Lac	H7R	154	4	9	6	9	2
13	Sainte-Dorothée	H7X	148	6	15	16	15	2
14	Auteuil-Nord-est	H7J	101	3	13	8	8	8
15	Auteuil	H7H	61	2	5	4	6	0
16	Laval-des-Rapides	H7N	60	6	10	10	9	2
17	Auteuil-Sud	H7K	48	3	3	3	2	2
18	Duvernay-Est	H7A	18	4	5	5	2	3
19	Îles-Laval	H7Y	3	0	0	0	0	1

*The statistics of Chomedey combines subdivisions of Chomedey Nord-est (H7S), Chomedey Est (H7V), Chomedey Nord-ouest (H7T), and Chomedey Sud (H7W)

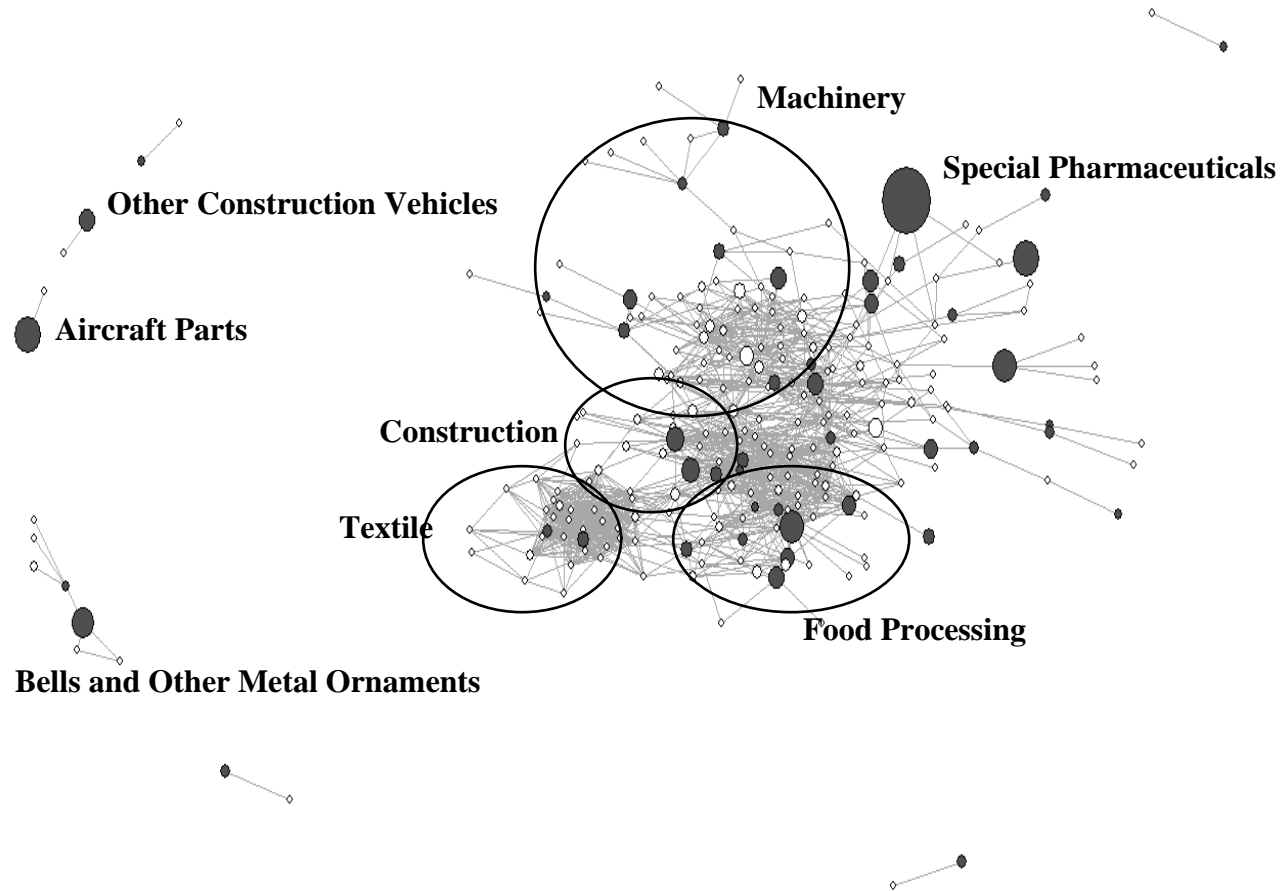
Figures

Figure 1: Product Space Network of the City of Laval



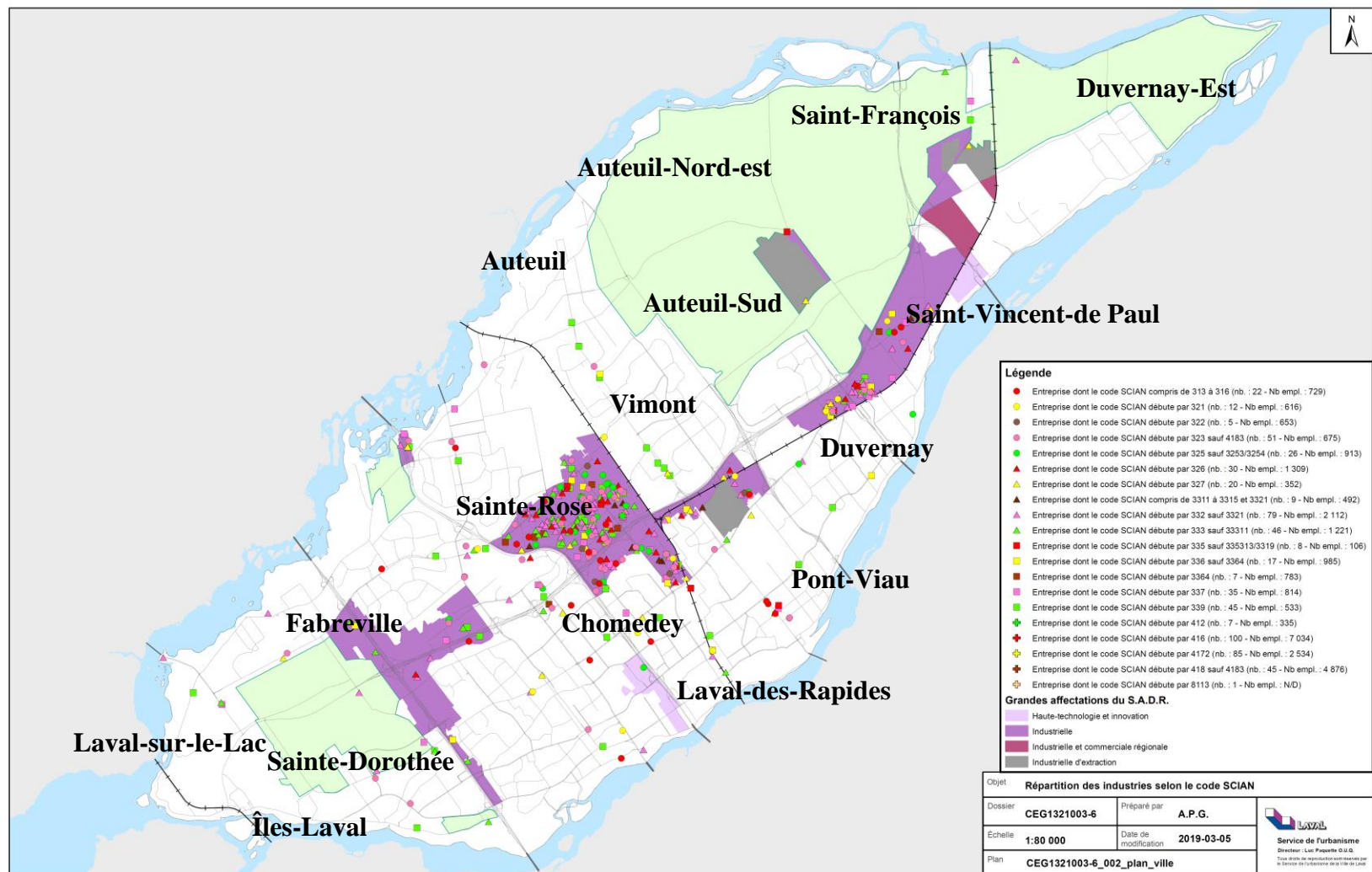
Note: Node size represents number of employees, black nodes represent high complex RCA sectors ($PCI > 0$, $RCA > 1$), grey nodes represent low complex RCA sectors ($PCI < 0$, $RCA > 1$), white nodes represent non-RCA sectors ($RCA < 1$).

Figure 2: First-degree Ego Network of RCA Sectors of the City of Laval



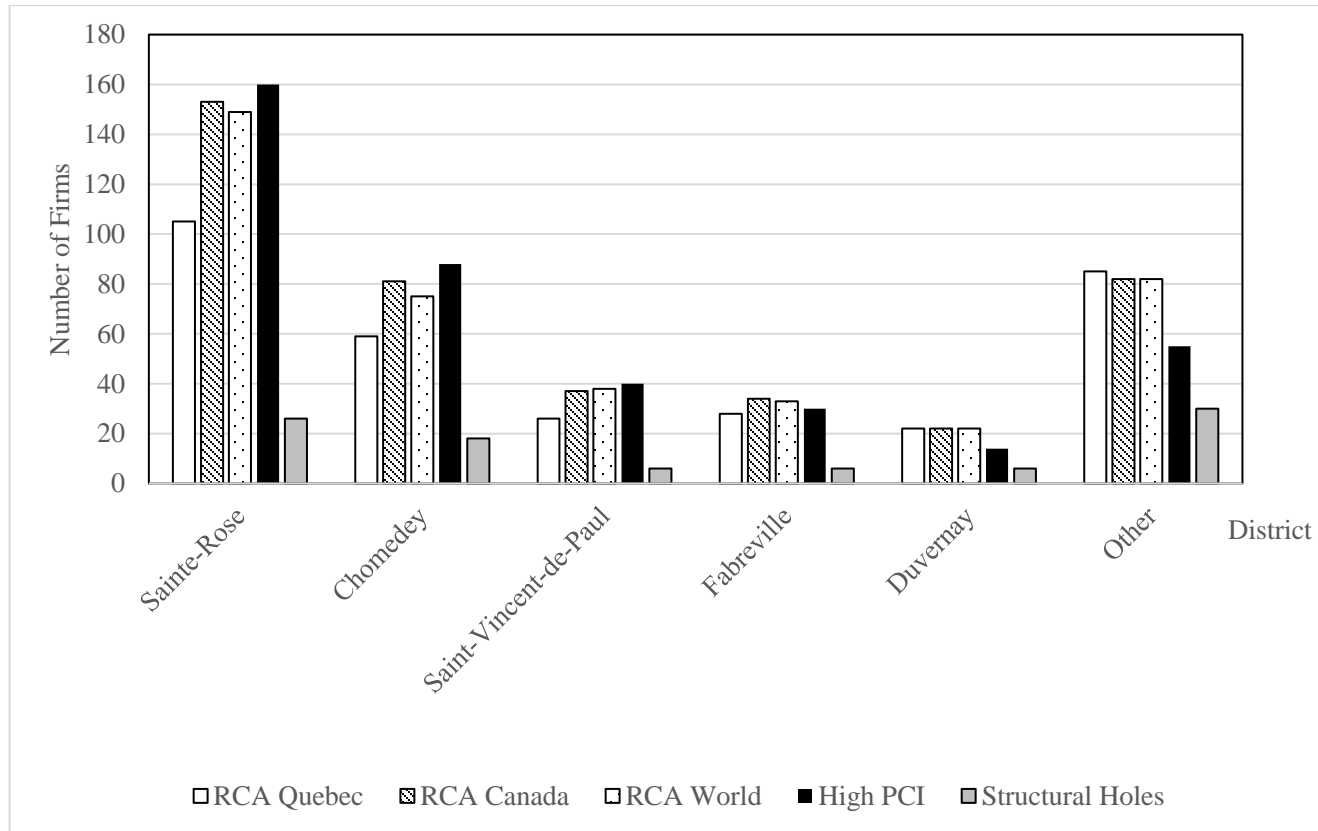
Note: Node size represents number of employees, black nodes represent high complex RCA sectors ($RCA > 1$), white nodes represent non-RCA sectors ($RCA < 1$).

Figure 3: Distribution of Manufacturing Firms in Municipal Districts of the City of Laval



Source: the City of Laval Economic Development Service (Service du Développement économique de Ville de Laval, SDÉ)

Figure 5: Number of Firms by Manufacturing sectors in Municipal Districts



Note: The statistics of Chomedey combines subdivisions of Chomedey Nord-est (H7S), Chomedey Est (H7V), Chomedey Nord-ouest (H7T), and Chomedey Sud (H7W)

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