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Résumé de l'article

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Competitividad industrial y oportunidades de IED en la periferia metropolitana - Análisis de la red del espacio de productos de Laval, Canadá

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ABSTRACT

This paper investigates the industrial competitiveness and FDI opportunities in the metropolitan periphery embedded in the product space network. Assessing the knowledge complexity and revealed competitive advantage (RCA) of local industries, entrepreneurs and policymakers can identify the most prominent ones and implement competitive strategy accordingly. Complementarily, they can attract FDI inflows in non-RCA structural hole sectors of close knowledge proximity with existing RCA sectors in the product space network. In the case study of Laval, Canada, we conduct quantitative product space network analysis and qualitative thematic analysis on the semi-structured interviews with entrepreneurs and policymakers to address these points.

Keywords: product space network, FDI, economic complexity, metropolitan periphery, structural hole

Résumé

Cet article étudie la compétitivité industrielle et les opportunités d'IDÉ dans la périphérie métropolitaine intégrée dans le réseau d'espace produit. Évaluant la complexité des connaissances et l'avantage comparatif révélé (ACR) des industries locales, les entrepreneurs et les décideurs politiques peuvent identifier les secteurs les plus importants et mettre en œuvre une stratégie concurrentielle en conséquence. En complément, ils peuvent attirer des flux d'IDÉ dans les secteurs des trous structuraux à forte proximité de connaissances avec ceux d'ACR élevé dans le réseau d'espace produit. Dans l'étude de cas de Laval, Canada, nous effectuons une analyse quantitative du réseau d'espace produit et une analyse thématique qualitative des entretiens semi-structurés avec les entrepreneurs et les décideurs politiques pour adresser ces points.

Mots-Clés : réseau d'espace produit, IDÉ, complexité économique, périphérie métropolitaine, trou structural

Resumen

Este artículo investiga la competitividad industrial y las oportunidades de IED en la periferia metropolitana, integradas en la red del espacio de productos. Al evaluar la complejidad del conocimiento y la ventaja competitiva revelada (VCR) de las industrias locales, los empresarios y los responsables políticos pueden identificar las más destacadas y aplicar una estrategia competitiva en consecuencia. De forma complementaria, pueden atraer flujos de IED en sectores no VCR con agujero estructural de estrecha proximidad de conocimientos con VCR existentes en la red del espacio de productos. En el estudio de caso de Laval (Canadá), realizamos un análisis cuantitativo de la red del espacio de productos y un análisis temático cualitativo sobre las entrevistas semiestructuradas con empresarios y responsables políticos para abordar estos puntos.

Palabras clave: red de espacio de productos, IED, complejidad económica, periferia metropolitana, agujero estructural

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Contemporary global business landscape is characterized by technological innovation led by digitization and increasing cross-border partnerships. Novel knowledge is generated, transferred, and acquired worldwide through FDI flows and global value chains (Bathelt & Li, 2020, Cano-Kollmann *et al.*, 2016, Kano, 2018, Lorenzen *et al.*, 2020, Perri & Peruffo, 2016). Thereafter, the capability of developing knowledge-intensive sectors and enhancing the connectivity in trade and investment networks define the industrial competitiveness of a country or a region (Davies & Maré, 2021, Iammarino, 2018, Mewes & Broekel, 2020). Based on these assumptions, research in *economic complexity*[1] provides a holistic paradigm for the study of a country/region's industrial competitiveness. The diversity of local export sectors with high *knowledge complexity* indicates a country/region's competence of conducting business activities in the non-ubiquitous innovation-oriented industries (Balland & Rigby, 2017, Hidalgo & Hausmann, 2009). The "complexity" of knowledge input in the industrial sectors and the "connectivity" in the cross-border trade and investment networks contribute to a country/region's industrial competitiveness on a global scale. On this ground, entrepreneurs and policymakers can explore and exploit business opportunities to attract FDI inflows embedded in the *product space network* (Davies & Maré, 2021, Hidalgo, 2021, Mewes & Broekel, 2020, Wang & Turkina, 2020).

At the regional level, the core-periphery hierarchy of metropolitan area, the basic territorial unit of regional development (Friedmann, 1966), constrains the potential of developing knowledge complex industries and territorial competitiveness in the urban system. Endowed with well-developed infrastructure, abundant venture capital, and highly qualified human capital, metropolitan core undertakes the most innovative economic activities. Moreover, facilitated by the FDI spillover effect, the metropolitan core coordinates local-global knowledge exchanges among key stakeholders in the regional innovation ecosystem (Balland *et al.*, 2020, Boschma *et al.*, 2014, Fritz & Manduca, 2021). Meanwhile, absorbing the outsourced resource and labor-intensive industries, metropolitan periphery supports the technology and capital-intensive industries in the core, thus becoming the affiliated economic hinterland. Nonetheless, due to the lack of the innovation-related economic factors and lower degree of connectivity to the global market, metropolitan periphery is generally less attractive to FDI inflows in developing knowledge complex sectors than the core (Pain, 2008, Santangelo, 2009). On the other hand, disruptive innovation in ICT technology and transportation mobility generates novel business models that enable employees work remotely. Metropolitan periphery takes the advantage of cost affordability and space accommodation to attract new business ventures and FDI inflows that relocate from overcrowded and expensive downtown areas (Delventhal *et al.*, 2021, Kang *et al.*, 2020). The outbreak of COVID-19 pandemic further accelerates the digital transformation of many enterprises and triggers the backflow of innovation-related resources, capital, and talents from metropolitan core to the periphery. These new dynamics of industrial transformation encourage policymakers in the metropolitan periphery to autonomously develop industrial policies, which aim at attracting FDI inflows with complementary knowledge spillovers beyond the demands of the metropolitan core.

This paper aims to identify the metropolitan periphery's FDI opportunities based on its industrial competitiveness in the *product space network*. First, we review the literature on the urban system of metropolitan area to underline the dynamics of industrial competitiveness in the metropolitan core and periphery. Then we refer to the building blocks of economic complexity theory and elaborate on the process of identifying globally competitive industrial sectors by calculating the *revealed comparative advantage* (RCA), and by spotting FDI opportunities related to the *structural hole* (Burt, 1992) in the *product space network*. To support our arguments, we analyze the building blocks of economic complexity of Laval, a peripheral municipality of Canada's second-largest metropolitan area – Montréal Metropolitan Area (Greater Montréal). Then, we conduct semi-structured interviews with local entrepreneurs and policymakers to provide further support to our arguments. Based on the analysis of the *product space network* structure and the interview discourse, we conclude with the strategic implications for international management in enhancing the metropolitan periphery's local economic complexity and global investment connectivity.

Literature review

Innovation in the metropolitan core-periphery

In the innovation-oriented global economy, the contributions of FDI inflows to a country/region's industrial competitiveness are broadly acknowledged in research in international business (Buckley *et al.*, 2009, Cano-Kollmann *et al.*, 2016, Kano, 2018, Perri & Peruffo, 2016), economic geography (Balland & Rigby, 2017, Bayliss, 2007, Mewes & Broekel, 2020, Turkina *et al.*, 2016) and innovation management (Arikan, 2009, Bathelt & Li, 2020, Cohendet *et al.*, 2010, Iammarino, 2018). Multinational enterprises (MNEs) establish subsidiaries or joint ventures in the host country and share technological and market knowledge with co-located local business partners through collaborations and spillovers (Bathelt & Li, 2014, Cantwell, 2009, Perri & Peruffo, 2016). In particular, in knowledge complex industries, incoming MNEs interact with diverse local stakeholders (e.g. local enterprises, government, R&D centers and universities, communities, industrial clusters) in innovation activities and diffuse knowledge spillovers through FDI pipelines. Thereafter, they become embedded in the local business networks and integrated in the regional innovation ecosystem.

At the subnational level, cross-border innovation collaborations and the FDI spillovers are not evenly distributed in the metropolitan area, which serves as the basic territorial unit of regional development (Balland & Rigby, 2017, Boschma *et al.*, 2013, Rodríguez-Pose, 2008).

1. The definitions of key concepts in italic text are presented in Table 1.

Generally, the metropolitan area consists of a central "core" and its surrounding suburban and rural "periphery" (Friedmann, 1966). Acting as principal innovation hubs, densely populated metropolitan cores benefit from well-connected infrastructure in transportation and communication, openness to the global trade and financial market, and agglomeration of innovation-related production factors (e.g. high-tech assets and facilities, highly skilled human capital, access to venture capital investment and specialized services) (Balland *et al.*, 2020, Lorenzen *et al.*, 2020, Pain, 2008). In the metropolitan core, a large number of anchor firms in knowledge complex sectors (e.g. financial services, ICT sectors, managerial consulting, logistics services, design and advertisements) tend to agglomerate in central business districts (CBDs). Incubating entrepreneurial opportunities for the local startups and entrepreneurs, anchor firms coordinate the innovation ecosystem of metropolitan areas and create job opportunities for highly qualified workforce (Colombelli *et al.*, 2019, Fabrizio, 2009, Feldman, 2005).

To optimize the manufacturing and operating costs, anchor firms in the metropolitan core outsource low knowledge complex activities (e.g. agriculture, mining and energy, standardized manufacturing and services) to their subsidiaries or subcontractors located in more spacious and less expensive suburban and rural territories (Arikan, 2009, Berman *et al.*, 2020, Pain, 2008). Through the coordination of the anchor firms, metropolitan periphery is integrated in the global business networks and becomes economically affiliated to the metropolitan core (Friedmann, 1966, Rodríguez-Pose, 2008, Turkina *et al.*, 2020). However, such economic dependence on the core pushes the metropolitan periphery into the disadvantageous position with lower attractiveness to FDI inflows in innovation-related activities. Furthermore, firms in the metropolitan periphery constantly face the "falling behind" challenges of under-investment in infrastructure, low adaptation to new technology, exodus of highly skilled workforce, and disconnection with the global market and international partners (Berman *et al.*, 2020, Felzensztein *et al.*, 2013, Scott & Storper, 2005). Therefore, it is not uncommon to observe "international connectedness" of FDI inflows in the highly competitive metropolitan core, and "local disconnectedness" of laggard suburban and rural periphery within the same metropolitan area (Iammarino, 2018, Lorenzen *et al.*, 2020).

To break out the polarization of core-periphery divergence, Copus (2001) called for a transition of polycentric "aspatial peripherality" in the metropolitan area. In addition to the local core-periphery interaction, enterprises and policymakers in the metropolitan periphery can autonomously incubate new technological capabilities by collaborating with foreign partners in business sectors with technological complementarity, which will help to sustain economic growth in the long run (Berman *et al.*, 2020, Dawley, 2014, Hidalgo, 2021). Therefore, it is crucial for entrepreneurs and policymakers in the metropolitan periphery to identify the most competitive business sectors with high "complexity", as well as to enhance the global "connectivity" by attracting FDI inflows in complementary sectors (Cano-Kollmann *et al.*, 2016, Iammarino, 2018, Kano, 2018, Wang & Turkina, 2020).

Economic complexity, product space network and industrial competitiveness

The transition towards innovation-oriented economy provides metropolitan periphery with new opportunities to reshape its industrial competitiveness on a global scale. Local firms' capability in processing complex knowledge as well as their connectivity in international business networks become crucial determinants of metropolitan periphery's position in the global competition. On the grounds of knowledge complexity and network connectivity, Hidalgo *et al.* (e.g. 2007, 2009, 2014, 2021) developed a series of holistic frameworks of *economic complexity* and *product space network* approach to tackle these issues. As a comprehensive theoretical paradigm of the knowledge-based industrial competitiveness, the economic complexity theory consists of several building blocks to measure the industrial complexity and global connectivity of regional development (Detailed definitions and calculations see Table 1 and Appendix), including (1) *Revealed competitive advantage (RCA):* a region's industrial competitiveness in specialized production of a given industrial sector. (Balland & Rigby, 2017, Fritz & Manduca, 2021, Hidalgo, 2021, Hidalgo & Hausmann, 2009); (2) *Product complexity index (PCI)*: the composition and sophistication of the intellectual input in the development of an industrial sector. The calculation of PCI is based on the ubiquity of products and the diversity of all countries' RCA sectors embedded in the *product space network* (Hidalgo *et al.*, 2007); (3) *Product Space Network (PSN):* the nexus of industrial sectors linked by high degree of *knowledge proximity* in terms of similar contextual basis or procedural sophistication. (Balland & Rigby, 2017, Hidalgo *et al.*, 2007, Simoes & Hidalgo, 2011); (4) *Economic Complexity Index (ECI):* ECI measures a country/region's capability of developing a large variety of non-ubiquitous industrial sectors with high knowledge complexity. (Balland *et al.*, 2019, Hidalgo & Hausmann, 2009, Wang & Turkina, 2020).

In the metropolitan area, the building blocks of economic complexity paradigm can be helpful to reshape innovation-oriented industrial policy and reduce the gap between metropolitan core and periphery in the global context (Balland *et al.*, 2020, Iammarino, 2018). To identify the industrial competitiveness of the periphery, entrepreneurs and policymakers can consider how many RCA sectors local businesses are specialized in, as well as whether these RCA sectors are of high PCI values positioned at the center of the *product space network*. Then they can strategically focus on enhancing these sectors by replenishing strategic resources, enhancing the skills of human capital, extending the outreach of business networks, and implementing favorable industrial policy. In practice, these methods have started to be applied in industrial strategy at subnational level in the European Union (Balland *et al.*, 2019), the USA (Balland *et al.*, 2020, Boschma *et al.*, 2014), China (Gao *et al.*, 2021), Canada (Wang & Turkina, 2020), Spain (Boschma *et al.*, 2013), New Zealand (Davies & Maré, 2021) among many other countries.

FDI opportunities in the product space network structural holes

Another important application of the economic complexity theory in regional development is how to spot FDI opportunities in the *structural holes* across the RCA sectors in the *product space network*. The knowledge spillovers among co-located local firms and foreign subsidiaries generate context-specific market knowledge sharing and formation of specialized clusters (Bathelt & Li, 2014, Cantwell, 2009, Perri & Peruffo, 2016). Knowledge exchanges through FDI flows generally follow two approaches: (1) Sharing complementary knowledge in building horizontal alliances based on common knowledge base and trust, and (2) Acquiring supplementary knowledge in establishing vertical supplier-buyer relationships based on absorptive capability in proceeding complex knowledge (Buckley *et al.*, 2009, Giroud & Scott-Kennel, 2009, Turkina & Van Assche, 2018). In the process of knowledge exchange through FDI inflows, local firms can leverage the existing resources and capabilities to absorb complementary knowledge of similar context or acquire supplementary knowledge of similar sophistication (Bathelt & Li, 2020, Iammarino, 2018, Perri & Peruffo, 2016).

TABLE 1
Definitions of key concepts of economic complexity theory

Concept	Definition	Note
Economic complexity	A country/region's capability in producing diverse categories of non-ubiquitous products that other countries or regions can hardly duplicate. It is measured by *Economic Complexity Index (ECI).*	If a country/region has a broad range of RCA sectors of high PCI values, this country or region has a high level of economic complexity index (ECI). These high ECI economies are more competitive than low ECI economies that only have a handful of RCA sectors of low PCI.
Knowledge complexity	The composition and sophistication of the intellectual input in the development of an industrial sector. It is measured by *Product Complexity Index (PCI).*	A positive PCI value indicates the high knowledge complexity in the technology or capital-intensive sectors with high growth potential. Vice versa, a negative PCI value indicates low knowledge complexity in the resource or labor-intensive sectors with low growth potential.
Product space network	A nexus of industrial sectors linked by high degree of knowledge proximity in terms of similar contextual basis or procedural sophistication. The nodes represent industrial sectors of different levels of knowledge complexity and the linkages represent the high degree of knowledge proximity of connected sectors (Hidalgo, 2021, Hidalgo *et al.*, 2007).	The generic product space network integrates UNCTAD annual trade data of more than 1200 items of commodities categorized in the harmonized system (HS). High PCI sectors are positioned at the center of the product space network, whereas low PCI sectors are allocated at the network periphery.
Revealed competitive advantage (RCA)	The proportion of production values of a given industrial sector over total regional economic output value in the designated region divided by the global average of the same ratio. On the global level, if RCA of a given sector is greater than 1, it indicates the designated region has global competitiveness in this industrial sector.	Since RCA is a dimensionality reduction term of ratio, other economic output indicators such as employment, patents, payroll, and value-added can replace trade values as measurements for RCA. On the national or subnational levels, if RCA of a given sector is greater than 1, it indicates that the designated regional has domestic competitiveness in this industrial sector.
Structural hole	The gaps among unconnected players in a network. In the social networks, "structural holes" represent the "common third party" that separates indirectly connected agents (Burt, 1992).	In this research we identify non-RCA sectors with direct linkage to existing RCA sectors as the structural hole in a region's product space network.
Knowledge proximity	The similar contextual basis or procedural sophistication in knowledge exchanges between two industrial sectors.	It represents the shared common knowledge base in new product development, and the tendency of co-location in spatial areas among enterprises (Antonelli, 2004).

To identify the potential sectors for attracting FDI inflow, it is important to explore *knowledge proximity*, the shared common knowledge base in new product development (Antonelli, 2004) across connected industrial sectors in the *product space network*. By searching for industrial sectors with high *knowledge proximity* to existing competitive sectors, entrepreneurs and policymakers can further explore and exploit new business opportunities in attracting FDI inflows. In the *product space network*, there are non-RCA sectors directly linked to RCA sectors. In the social networks, "*structural holes*" represent the "common third party" that separates indirectly connected agents (Burt, 1992). Following this definition, we identify non-RCA sectors that extend direct linkages to existing RCA sectors as the *structural holes* in the *product space network*. Compared to other non-RCA sectors, *structural holes* share a higher degree of *knowledge proximity* to existing RCA sectors, thereafter, are more likely to leverage existing resources and capabilities to become new RCA sectors with global competitiveness (Wang & Turkina, 2020). Thus, FDI inflows from foreign countries with industrial competitiveness in the *structural holes* provide new opportunities in incubating new RCA sectors by sharing related complementary knowledge base or facilitating complex supplementary knowledge acquisition. Simultaneously, local firms benefit from localized spillovers of foreign FDI subsidiaries in the *structural holes*. Through the global-local interactions in the *structural holes*, local firms in the metropolitan periphery reshape new growth paths of global connectivity (Balland *et al.*, 2015, Neffke *et al.*, 2011). In sum, the knowledge complex FDI inflows in the *structural holes* leverage the existing local capabilities by enhancing the local *economic complexity*, thus further contribute to the industrial competitiveness of the metropolitan periphery.

Case study of Laval, Canada: Methodology and data collection

Methodology

To demonstrate how a metropolitan periphery identifies its industrial competitiveness and FDI opportunities, we adopt a hybrid analytical approach of quantitative analysis of local *product space network* structure and qualitative analysis of the semi-structured interviews with entrepreneurs and policymakers. Furthermore, we undertake a case study of the City of Laval, a medium-sized Canadian city in the Province of Québec to fulfil these research objectives.

Grounded on the building blocks of *economic complexity* and the generic structural layout of the *product space network*, we calculate the RCA indices of the local industrial sectors and identify sectors of global competitiveness with RCA value greater than 1. Then, we compare the degree of PCI of these RCA sectors, and further select knowledge complex industries with positive PCI values. To understand whether the global competitive sectors are equivalently competitive in the domestic market, we can replace the denominator or RCA by the proportion of export value of the designated product over the total regional export value at national or subnational levels following the pattern introduced by of Wang & Turkina (2020). After that, we approach the first-degree ego networks of RCA sectors with positive PCI values as the *structural holes* to attract FDI inflows. We also refer to the leading exporting countries of these *structural holes* as potential business partners. Furthermore, we argue how the identification of *structural holes* in the *product space network* serves as a practical tool for entrepreneurs and policymakers to spot the potential fields to develop global competitiveness based on existing industrial capabilities.

To affirm the practical implications of the analysis, we conduct semi-structured interviews with local policymakers and entrepreneurs. These interviews interpret entrepreneurs' call for government support in enhancing local industrial competitiveness and global connectivity. We also present policymakers' responses related to developing competitiveness-based strategy in attracting FDI inflows in the *structural holes*. After collecting the first-hand interview data, we proceed with thematic analysis to understand the entrepreneurs' needs in enhancing local industrial competitiveness and global connectivity, as well as their visions on the future efforts the policymakers that meet these goals.

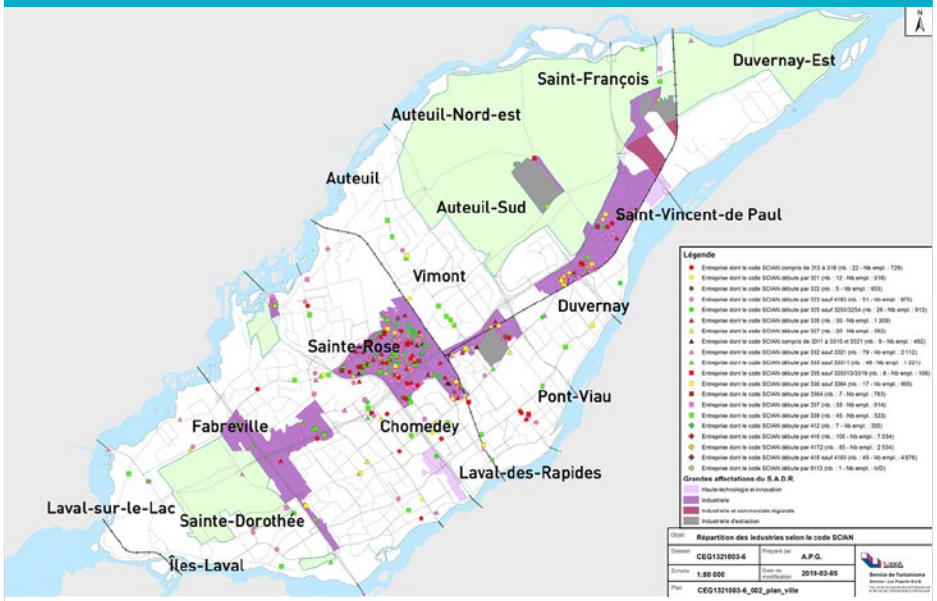
In the empirical analysis, we conduct an in-depth analysis of the *product space network* of Laval as a representative case. The selection of Laval as a representative case of the metropolitan periphery is based on the geographic, industrial, and political criteria. From the geographic perspective, Laval is located within the of the Montréal Metropolitan Community (MMC, also known as "Greater Montréal"), the second most populous metropolitan area in Canada. The local economy of Laval has strong connections with the metropolitan core in Montréal, while also maintain a complete and autonomous economic ecosystem. Therefore, the location and urban structure of Laval fulfil the criteria of a metropolitan periphery. From the industrial perspective, the economic structure of Laval is characterized by hybrid economic structure of the metropolitan periphery with strong presence of both resource and labor-intensive sectors with low knowledge complexity and capital and technology-intensive sectors with high knowledge complexity. From political perspective, local policymakers in Laval aim to develop FDI policies that are independent from the metropolitan core in Montréal. Supporting the local industrial upgrading, the municipal government of Laval created the agency *Laval Économique* that supports local SME development, implement industrial policies, and coordinate multilateral business relationships. In all, a mixed-method analysis of the case study of Laval well serves the purpose of this research.

The City of Laval, Canada

The City of Laval (*Ville de Laval*) was created in 1966 by merging 14 independent municipalities on the Jesus Island (*Île Jésus*) to the north of Montréal. With more than 400 thousand inhabitants, Laval has currently grown as the third most populous municipality in Québec, only after Montréal and Québec City. Historically, Laval lacks a city center and its urban functions are dispersed in 16 municipal districts (See Figure 1). A large part of territories of Laval are agricultural areas, whereas there are three divisions of industrial agglomerations along the 440 Highway, namely Central (Sainte-Rose, Chomedey Nord-est, Chomedey Est, Chomedey Nord-ouest), East (Saint-Vincent-de-Paul, Duvernay). Serving as the "banlieue-dortoir" (dormitory suburb) for decades, Laval accommodates the development of urbanization and population emigration from the metropolitan core of Montréal (Fischler & Wolfe, 2000).

The local industrial landscape of Laval is highly diversified with well-developed sectors of both low knowledge complexity (e.g. agriculture, food processing, textile, mining) and high knowledge complexity (e.g. bio-pharmaceutics, aerospace, machinery manufacturing). Currently, agricultural zones occupy more than 30% of the territories of the Laval, and food processing is one of the most important local job providers. On the other hand, thanks to the improvement in transportation infrastructure connectivity, the increasing inflows of highly qualified workforce (especially those with immigration background), and relatively lower population density and large industrial area (30 million square feet [approximately 2,787 km^2]) yet to be developed, Laval undertakes multiple commercial and industrial development projects from nearby Montréal. Home to the Biotech City (Cité Biotech), Laval hosts a large number of high-tech firms in biopharmaceutical sector and life sciences R&D centres (including a suburban campus of the University of Montréal). Meanwhile, thanks to the global competitiveness of Québec in the aerospace industry (Niosi & Zhegu, 2005, Turkina *et al.*, 2016, Wang & Turkina, 2020), numerous aerospace enterprises and their suppliers also establish manufacturing plants in Laval. Additionally, approximately 60% of the local population work in service sectors (household service 34.0%, public service 21.2%), followed by trade (18.95%), manufacturing (16.26%), public administration (4.59%), and agriculture (0.42%) (Québec Statistical Institute, 2020) (See Table 2).

FIGURE 1
Municipal districts and manufacturing firms of Laval, Canada



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

To promote the local industrial upgrading and establish an autonomous economic ecosystem, the municipal government of Laval established its economic development division *Laval Économique* to implement its innovation-oriented industrial policy and global business development strategy. The main missions of this agency include financial solution proposition and solicitation, commercial property search and management, staff recruitment and training, innovation project incubation, and international business network integration. It offers financial and policy support to local firms in the innovation-oriented sectors and attract FDI inflows to sustain the global connectivity and competitiveness of local industries. Currently, the employment of knowledge complex industries are concentrated in the three strategic industries including life sciences (more than 5,000 jobs, 100 companies, 11 R&D centers, more than 3 billion Canadian dollars of investment since 2001), aerospace industry (nearly 2,500 jobs, 30 companies, incorporated in the Aéro Montréal aerospace cluster) and the bio-food industry (118 processing establishments, 11% of the region's jobs, 7% of regional GDP in 2019) (Wang & Turkina, 2021).

TABLE 2

Top 15 employment manufacturing sectors of the City of Laval

Rank	SH Code	Product	PCI	Employment	RCA	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

Data collection

Upon the request of the municipal government of Laval, we undertake a research mandate on the industrial competitiveness and FDI opportunities from the *Laval Économique*, the municipal policymaker in regional economic development. The main aims of this research mandate include (1) reviewing the literature on regional *economic complexity* and *product space network* to address the necessity of the research in industrial upgrading; (2) map the *product space network* of the City of Laval and calculate the *Revealed Competitive Advantage* (RCA) Indices of local business sectors; (3) analyze the structural features of the *product space network* and identify the *structural holes* among the RCA sectors as opportunities for establishing global pipelines in trade and investment; (4) summarize the policy implications of empirical analysis for regional innovation strategy in industrial upgrading.

Following these guidelines, we incorporate the industrial statistics in the *product space network* configurations. Then, we identify the RCA sectors of various PCI levels, and compare whether industrial sectors with industrial competitiveness are evident to the same degree at national and subnational level. Furthermore, we identify the *structural holes* in the *product space network*, then search for the world's largest exporters in the *structural holes* as potential FDI sources as well as largest importers in the same sectors as potential overseas market.

To identify RCA sectors and *structural holes* of Laval, we first collect the corporate attribute data of local manufacturing enterprises from credible official industrial datasets of Québec Province in Canada, including Banque d'information industrielle of the Centre de recherche industrielle du Québec (CRIQ) and Registraire des entreprises du Québec (REQ). These attributes include enterprise name, Québec enterprise number (le numéro d'entreprise du Québec, NEQ), industrial sector (North American Industry Classification System [NAICS] Canada 2017), addresses of local establishments with postal code, number of employees, year of foundation, and sales revenue.

Then we build up the general *product space network* by tracking the dyadic linkages between four-digit harmonized system 1992 standard (HS92) provided by *the Atlas of Economic Complexity* (Simoes & Hidalgo, 2011) To indicate the knowledge complexity of embedded industrial sectors, we calculate the 6-year average PCI indices of each HS92 product category from 2012 to 2017 as the measurement for the knowledge complexity of production activities. If the average PCI is positive, we note the sector of high degree PCI.

After that, we integrate the corporate attribute data in the general produce space network framework and calculate the RCA index of each sector accordingly. Based on existing manufacturing data, we mostly focus on 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 registers 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). To compare the industrial competitiveness of manufacturing firms in Laval with their local competitiveness, we additionally match the trade data provided by provincial (Institut de la statistique du Québec), national (Statistics Canada), and global (UN Comtrade Database) statistics authorities as the denominators of RCA calculation (See Appendix). Since a large majority of local enterprises in Laval do not engage in export activities, we calculate the municipal level RCA index by referring to the number of employees in each sector over the total number of employed population. This adjustment goes in line with the strong correlation between workforce inflows and concentrated economic activity volume in the most competitive sectors (Hidalgo, 2021). Once the RCA sectors were determined, we continued identifying *structural holes* in the *product space network*. We researched the first-degree direct connects of all RCA in their ego networks, then integrated these separate ego networks into the local *product space network*. We compared the PCI of all identified RCA sectors and *structural holes* as FDI opportunities, thereafter, analyzed the structural features of their distribution in the *product space network* of Laval.

To reconfirm our findings, we conduct subsequential follow-up survey and telephone interviews with local entrepreneurs and policymakers and question them on their perspectives of the industrial competitiveness and challenges of Laval. Following the contact list of the entrepreneurs provided by *Laval Économique*, we contact 608 entrepreneurs of SMEs in Laval from October 2020 to January 2021. In return, we receive 84 valid responses (response rate =13.82%) to the survey. Whereas most of these entrepreneurs work in the manufacturing sectors, we also receive feedback from professionals in agricultural, trade and service sectors. Furthermore, a dozen of the entrepreneurs agree to accept interview requests and provided more detailed industrial insights.

We record the original interview transcripts and aggregate the main themes of the subjects including (1) Innovation activities of enterprises in Laval; (2) Main challenges of local enterprises (lack of skilled labor, underdeveloped public transportation, need for government support); (3) Perspectives of policymaking and support (financial subsidies and tax credit, industrial cluster development, international business network expansion). All these industrial insights highlight the necessity and practical implications of understanding the local *product space network* configurations and identifying FDI opportunities in the *structural holes*. Finally, we conclude with several strategic implications for local entrepreneurs and policymakers in enhancing industrial competitiveness and developing business networks of the metropolitan periphery.

Product space network analysis of Laval

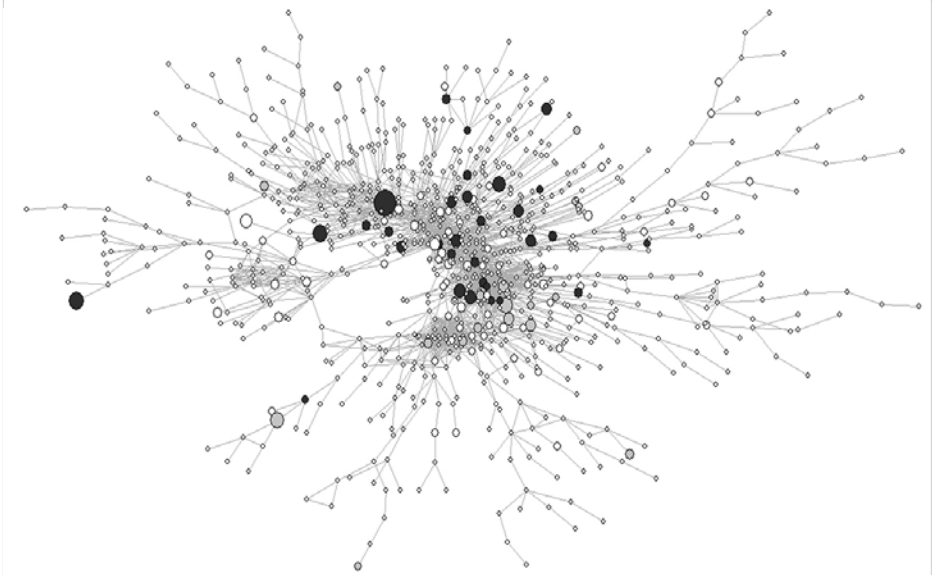
RCA analysis of industrial competitiveness

Incorporating the calculation results of RCA and PCI of local manufacturing sectors, we build up the *product space network* of Laval as exhibited in Figure 2. In the network, the node size represents the number of employees, and the node colour represents the degree of knowledge complexity.

First of all, we confirm that regardless of its status of the metropolitan periphery of Greater Montréal, Laval has independently developed "well-developed commercial sectors, dynamic professional and scientific services and a manufacturing industry"[2] (Canada Economic Development [CED] for Québec Regions). Among 1224 manufacturing sectors included in the *product space network* framework, enterprises of Laval conduct manufacturing activities in 132 sectors, which count for 10.87% of all embedded industrial sectors in the general *product space network*, and more than half of local manufacturing sectors are of positive PCI values (N=73, p=55.3%). By the world standard, Laval has in total 55 RCA sectors (41.7% of all local manufacturing sectors), more than half of which are of positive PCI (N=35, p=63.64%). This proportion of RCA sectors with positive PCI value is higher than the provincial average of Québec (p=52.49%) and national average of Canada (p=50.75%).

Coherent with the judgment of local policymakers, the leading employment sectors of Laval are life sciences (special pharmaceuticals, medical instruments), aerospace industry (aircraft parts), and food processing sectors (pig meat, baked goods) (See Table 3). To explain the competitiveness of knowledge complex sectors (especially bio-pharmaceutical industry), local policymaker remarks the unique facilities in abundant skilled labor, proximity to protected areas of natural resources, close R&D collaboration with *Institut National de la Recherche Scientifique* (National Institution of Scientific Research, INRS), financial incentives and tax credits for high-tech firms, and strategic location and well-developed transformation infrastructure[3]. In addition to these strategic sectors, specialized papermaking (newsprint), housewares (bell and other metal ornaments, furniture), and machinery and transportation vehicles (iron structures, vehicle bodies,

FIGURE 2
Product space network of Laval (Canada)



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

interchangeable tool parts, lifting machinery, construction vehicles, vehicle parts) sectors also provide numerous job opportunities. For the leading local employers, the main global competitors are the exporters from Germany and China. On the other hand, the USA, the largest trade partner of Canada and Québec (Wang & Turkina, 2020), 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. In terms of spatial distribution, Central Division (Sainte-Rose and Chomedey) concentrates most of job opportunities in Laval accounting for 71.93% of the total employment of the city, followed by East Division (Saint-Vincent-de-Paul, Duvernay) and West Division (Fabreville)

Nonetheless, by re-ranking the RCAs of local industrial sectors, we find that the most competitive ones exceed beyond the 3 strategic sectors (See Table 3). The leading sectors by RCA include 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). Therefore, the most employing sectors and most competitive sectors in terms of RCA are related but do not overlap. Policymakers should spot these "hidden champions" of non-strategic RCA sectors and provide institutional support for firms specialized in these industries to "scale up".

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

3. Source: Cité Biotech Laval: https://lavaleconomique.com/assets/docs/documents/190/de43-brochurebiotech21-fr-lr-937.pdf

The global competitors and partners of Laval's RCA sectors turn out to be more versatile. Generally, if a country is a world leading exporter of Laval's RCA sectors, we identify this country as a major competitor. *Vice versa*, if a country is a large importer of Laval's RCA sectors, we define this country as a potential partner. Following this criterion, Germany and China turn out to be the major global competitors of Laval's RCA sectors, whereas the USA is the main exporting market of the local enterprises of Laval. In addition, the competition from other emerging economies (e.g. Thailand, Turkey, Indonesia) also challenges the industrial competitiveness of local firms of Laval. In terms of exporting markets, Japan and EU countries (France and the Netherlands) emerge as potential destinations to form collaboration. Interestingly, in a few RCA sectors of Laval, the USA turns out to be the main competitor whereas China becomes a potential partner. For example, the world's largest export of scrap plastic is the USA, while the largest importer is China. Considering Laval's competitiveness in the sector (RCA =5,658), local plastic manufacturers should be aware of the high competition in the US market meanwhile consider forming supply chain partnership with customers in China.

Finally, to compare the divergence of competitiveness of Laval at global and domestic scales, we replace the denominator of the RCA formula with the average of exporting value of each sector over total exporting value at provincial level of Québec ($RCA_{Québec}$) and national level of Canada (RCA_{Canada}). From the result in Table 4, we figure out that the industrial competitiveness at local and global levels do not always overlap. In some sectors, Laval has higher local competitiveness than global competitiveness (e.g. bells and other metal ornaments, special pharmaceuticals, other metal fasteners). In contrast, some other sectors are more competitive in the global market than in the domestic market (See Table 4). Local enterprises in these sectors should concentrate on exploiting the new business potential in the provincial or national market, then seek new internationalization opportunities. For instance, aerospace parts manufacturing has long been considered a strategic industry for Laval. However, compared with other municipalities in Québec, Laval does not necessarily have evident local competitiveness in aircraft parts manufacturing at provincial level ($RCA_{Québec}$ =0.779). Nonetheless, with high RCA at national and global levels (RCA=1.827, RCA_{Canada} =1,242) and high knowledge complexity (PCI=0.641), local aircraft part manufacturers are well competent in competing in the global aerospace industry and forming strategic alliances with partners from overseas and other provinces of Canada. Another example is the large iron container manufacturing sector. Although the global RCA of this sector is greater than 1, Laval does not necessarily prevail over domestic competitors either at provincial level or national level. Hence, firms in such sectors have higher potential in exploring the global market to offset high competition in the domestic market. Navigating towards a global-oriented strategy, local firms should reconsider coordinating their competitive relations with counterparts in Québec and Canada.

In conclusion, characterized by the strong competitiveness in knowledge complex sectors, the economy of Laval not only benefits from the industrial transfer from the nearby metropolitan core of Montréal, but also incubates a complete and independent micro-ecosystem integrating local firms, employees, and governmental authorities. Meanwhile, the metropolitan periphery's industrial competitiveness is related but not

TABLE 3
Top 15 manufacturing sectors with highest RCA of the City of Laval

Rank	SH Code	Product	PCI	Employment	RCA	$RCA_{Québec}$	RCA_{Canada}	Top Exporter	Top Importer
1	8306	Bells and Other Metal Ornaments	-0.866	691	54,137	311,988	123,031	China	USA
2	4801	Newsprint	0.903	951	35,432	0.597	2,485	Canada	USA
3	4816	Other Carbon Paper	0.025	77	25,434	944,757	326,058	Thailand	Japan
4	3006	Special Pharmaceuticals	1,087	1956	22,524	23,573.010	45,639	Germany	USA
5	2001	Pickled Foods	-0.762	231	19,225	31,208	151,758	Turkey	USA
6	5901	Gum Coated Textile Fabric	-0.476	54	18,111	107,042	442,426	China	USA
7	8308	Other Metal Fasteners	0.392	334	16,036	198,405	114,667	China	France
8	8461	Metalworking Machines	1,676	200	14,202	45,820	33,678	Germany	China
9	8530	Traffic Signals	0.867	149	9,723	5,196	8,460	Germany	USA
10	8707	Vehicle Bodies	1,301	461	9,560	5,326	5,591	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	5,084	6,270	China	USA
13	3401	Soap	-1,234	426	6,627	2,994	5,388	Indonesia	USA
14	6117	Other Knit Clothing Accessories	-1,247	107	5,696	15,506	40,430	China	USA
15	3915	Scrap Plastic	-0.891	164	5,658	4,555	7,050	USA	China

TABLE 4

List of manufacturing sectors low local competitiveness and high global competitiveness ($RCA_{Québec}$ <1, RCA >1)

HS Code	Product	Employment	PCI	RCA	$RCA_{Québec}$	RCA_{Canada}	Top Exporter	Top Importer
8803	Aircraft Parts	974	0.641	1,827	0.799	1,242	USA	USA
4801	Newsprint	951	0.903	35,432	0.597	2,485	Canada	USA
203	Pig Meat	873	0.829	4,830	0.507	1,381	Germany	Japan
7308	Iron Struc-tures	535	0.442	1,864	0.750	1,870	China	Norway
8428	Lifting Ma-chinery	411	1,161	2,361	0.960	1,672	China	USA
2106	Other Edible Preparations	309	0.147	1,320	0.816	1,246	USA	UK
4818	Toilet Paper	75	0.166	1,156	0.183	0.586	China	USA
4408	Veneer Sheets	60	-0.708	3,180	0.451	0.812	China	India
7309	Large Iron Containers	30	0.111	1,364	0.573	0.980	China	USA

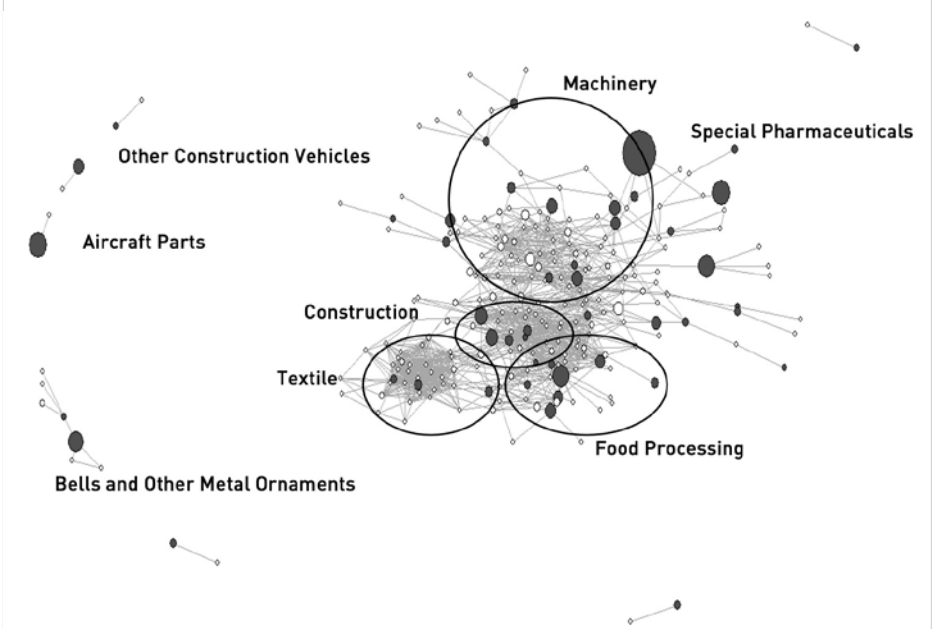
fully equivalent to concentration of factors of production (e.g. labor, resources, technology, etc.) and agglomeration in specialized enterprises. In words, the clustering effect is not a sufficient indicator of industrial competitiveness. For instance, although there is no metal manufacturing cluster in Laval, this sector has a prevailing global competitiveness based on RCA calculation. Meanwhile, the configurations of the input-output flows of the global value chains should also be taken into consideration within the *product space network* (Hidalgo, 2021). On the one hand, the upstream-downstream coordination within the value chains sustains the supplier-buyer relationship with the industrial correlation. On the other hand, the proximity within the *product space network* also implies the complementary knowledge sharing in the industrial upgrading process. For example, in Laval, the rising global competitiveness of metal product manufacturing is, to a certain extent, explained by the rising need from the downstream strategic sectors such as aerospace industry, vehicle parts manufacturing, and other machinery manufacturing. All these industries are of high PCI and contribute to the overall *economic complexity* and global competitiveness of Laval as a whole.

FDI opportunities in the structural holes of the product space network

In the *product space network*, *structural holes* represent non-RCA sectors that are directly connected with existing RCA sectors. From the first-degree ego network of RCA sectors of Laval (See Figure 3), we can first observe that there is a densely connected giant component that mixes both RCA and non-RCA sectors. At the network center, 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 sectors lack dense connections to other RCA sectors via the bridges over *structural holes*. At the edge of the network, we 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.

FIGURE 3

First-degree ego network of RCA sectors of the City of Laval

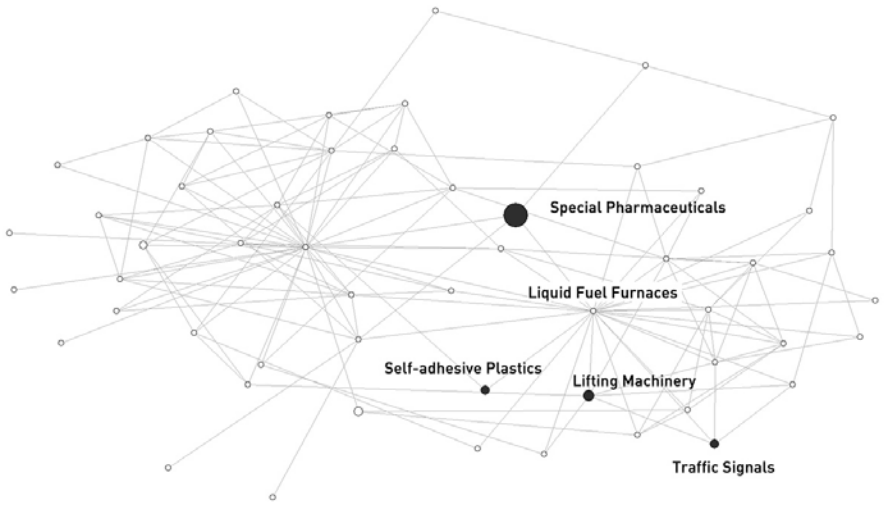


Note: Node size represents number of employees, black nodes represent high complex RCA sectors (RCA>1), white nodes represent non-RCA sectors (RCA <1).

To demonstrate how FDI opportunities in the *product space network* are identified, we explore the ego network of special pharmaceutical manufacturing sector (HS3006), the largest employment sector of Laval. In this network, we find that there is a *structural hole* in the sector liquid fuel furnaces (HS8416) that lies between special pharmaceutical manufacturing and other three RCA sectors, namely self-adhesive plastics, lifting machinery, traffic signals in the *product space network* (See Figure 4). Thereafter, attracting FDI inflows in liquid fuel furnaces manufacturing to establish local subsidiaries can leverage the existing resources and capabilities of other RCA sectors with high *knowledge proximity*.

FIGURE 4

Ego network of special pharmaceuticals sectors (HS3006)



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

Finally, we rank the PCI of all non-RCA sectors of the City of Laval and select those of positive PCI values (See Table 5). These sectors are those with the closest *knowledge proximity* to existing RCA sectors in the City of Laval, and of high growth potential. Most of these sectors are concentrated in machinery and transportation vehicles, chemicals, housewares and textile sectors, other than the three strategic sectors. Therefore, leading exporters (e.g. China and Germany) in these *structural holes* are the main sources to attract FDI, while local firms should continue exploring and exploiting the consumers' market in the nearby USA. Hence, Laval should concentrate on its efforts on attracting FDI inflows of top players in Asia and Europe while continue exploring sales channels to the nearby American customers.

TABLE 5

Structural holes of positive PCI values

SH Code	Product	Employment	PCI	RCA_	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

Semi-structured interviews to access industrial competitiveness and FDI opportunities

To confirm the practical implications of the analysis, we conducted semi-structured interviews with local entrepreneurs and policymakers regarding their views on (1) the evolution of industrial development in Laval (2) the local competitiveness building and government support in strategic sectors (e.g. biopharmaceutical industry, machinery manufacturing, aerospace industry) (3) future directions of industrial upgrading and FDI attraction in Laval. These interviews were conducted by in-person meeting, telephone communication, and email exchanges from September 2020 to April 2021. Then we processed the interviews using thematic coding approach to indicate the framework and present the interpretations (See Table 6).

TABLE 6
Thematic analysis of semi-structured Interviews

Theme	Discourse
Entrepreneurs' needs	
Infrastructure	*We need to bring the right infrastructure and the right projects to be able to attract more businesses and young families to continue to grow and evolve.* (Entrepreneur A)
R&D collaboration	*I would like to see something like that in Laval: an industrial cluster... It would open doors for us and allow us to create links between companies, but also to create bridges with university and R&D centers, this is something we would like to do, but which we find more difficult than expected.* (Entrepreneur B)
International development	*We really have to review our value chain and our expansion plans with the pandemic... We cannot continue with a single supplier or a single export market. We have to review our supply chain and, for our future plans, we are looking at which new markets to develop.* (Entrepreneur C)
Financial, technological, and regulatory support	*In fact, I used Laval's municipal services during the very beginnings of my business, when my start-up was in my garage, and it was just me! ... This is what allowed me to innovate and grow. When you are at the very beginning, with a totally innovative concept, it is difficult to find financial assistance. It was absolutely essential for me in order to build an innovative company.* (Entrepreneur D)
FDI inflow and HR development	*I would like to see better support, a real vision for Laval... The region needs to look at what is working well outside, in other regions, and even in other industries and do something similar here. This is how the region will be competitive and how we will encourage companies to come and settle here and people to come and live here. We have to propel the economy.* (Entrepreneur E)
Policymakers' reactions	
Industrial competitiveness	*For example, with low supply costs, particularly in raw aluminum and electricity production, the Laval metal smelting sectors and related equipment manufacturing sectors have developed solid competence. Such competence can further accommodate the needs of foreign direct investment, principal or supplier, wishing to join the value chain of metal products.* (Policymaker A)
FDI opportunities	*We are exploring several opportunities in various sectors, but for now we are primarily capitalizing on our strengths in the sectors already mentioned while developing and supporting an intensification of the complexity of knowledge in these sectors.* (Policymaker A)

We first interviewed local entrepreneurs on their needs regarding enhancing local industrial competitiveness and global connectivity. Several entrepreneurs expressed their concerns related to (1) Improving local infrastructure connectivity and attracting new businesses and talents; (2) Enhancing R&D collaborations with co-located stakeholders in industrial clusters; (3) Channelling pipelines of trade and investment with diverse global partners and markets.

The entrepreneurs also described their visions of the industrial upgrading in Laval and addressed their demand for the competitiveness-oriented strategy from local policymakers. The respondents emphasized their concern for (1) Meeting the need for financial, technological, and regulatory support from local government that assists the local start-up to scale up; (2) Placing attractiveness of FDI inflows and highly qualified talents in the long-term vision of regional development.

Therefore, the interviews confirm the necessity to implement competitiveness-oriented industrial policy based on innovation capabilities and global connectivity. To better serve the entrepreneurs' demands, local policymakers should have a clear assessment on the local industrial landscape, then channel FDI inflows with complementary knowledge spillovers based on existing competitiveness.

Next, we interviewed an industrial commissioner from the Economic Development Service of the City of Laval. His responses highlight the following aspects: (1) The development of knowledge complex industries in Laval is grounded on the existing industrial competitiveness; (2) The policymakers in the metropolitan periphery tend to focus on exploitation of existing competences than exploration of new domains in FDI attraction.

In conclusion, tackling the concerns of both entrepreneurs and policymakers in the metropolitan periphery, the economic complexity theory and *product space network* analysis provide practical tools that clarify the directions and measures to attract FDI. Based on the *knowledge proximity* to the existing RCA sectors, entrepreneurs and policymakers can search for the *structural holes* in the *product space network* and thereby identify FDI opportunities. Specifically, *structural holes* of high knowledge complexity are the most prominent fields to attract FDI inflows from countries with existing industrial competitiveness (Balland *et al.*, 2015, Hidalgo, 2021, Neffke *et al.*, 2011, Wang & Turkina, 2020). Furthermore, knowledge spillovers from FDI subsidiaries contribute to the "leapfrog" in regional industrial upgrading by creating job opportunities for talents, attracting new venture capital investment, and accelerating local start-up incubation and scale-up (Fritz & Manduca, 2021, Gao *et al.*, 2021, Mewes & Broekel, 2020, Perri & Peruffo, 2016).

Conclusions and Implications for future research

This research is an exploratory study that identifies the industrial competitiveness and FDI opportunities of the metropolitan periphery. Despite the existing inequality of competitiveness and connectivity (Davies & Maré, 2021, Iammarino, 2018, Lorenzen *et al.*, 2020), the metropolitan periphery can still implement autonomous policy that enhances the competitiveness of local industries with high knowledge complexity. The analysis is based on the building blocks of the economic complexity theory, including *revealed competitive advantage* (RCA) in specialized products, knowledge complexity measured by product complexity index (PCI), *knowledge proximity* and *structural holes* in the *product space network* (Balland & Rigby, 2017, Hidalgo, 2021, Hidalgo & Hausmann, 2009, Hidalgo *et al.*, 2007, Simoes & Hidalgo, 2011).

Theoretically, this paper brings in original conceptual contributions to understand the "complexity" and "connectivity" of a metropolitan periphery's industrial competitiveness (Hidalgo, 2021). By analyzing the *product space network* of Laval and comparing the RCA at global, national and subnational levels, we provide practical implications for entrepreneurs and policymakers to reorient the regional industrial strategy between global exploration and local exploitation. Furthermore, we address the role of the *structural holes* in the *product space network* as potential fields to attract FDI inflows thanks to their *knowledge proximity* to existing RCA sectors (Antonelli, 2004, Burt, 1992, Gargiulo & Benassi, 2000). By sharing complementary knowledge in horizontal linkages and acquiring supplementary knowledge in vertical linkages, these *structural holes* serve as intermediate value chain stages that channel global capital flows and knowledge

spillovers towards local production (Asheim *et al.*, 2011, Balland *et al.*, 2015, Giroud & Scott-Kennel, 2009, Wang & Turkina, 2020).

In practice, analyzing the RCA sectors embedded in the *product space network* provides entrepreneurs and policymakers in the metropolitan periphery with practical tools to understand the regional industrial competitiveness and FDI opportunities. The main global exporters of the RCA sectors are the major competitors in the global market, whereas the main importers of RCA sectors are the potential business partners of local industries. Furthermore, entrepreneurs and policymakers can compare the RCA at global, national and subnational levels. If an industrial sector has global competitiveness with RCA greater than 1, whereas the RCA values at national or subnational levels are lower than 1, it means the domestic market is over competitive and saturated. Global collaboration with leading importers in these industries is a prioritized strategy. *Vice versa,* if the RCA value of an industrial sector is low on a global scale, but high at national or subnational levels, local exploitation should be a more preferred strategy than internationalization.

Regarding the FDI opportunities, entrepreneurs and policymakers in the metropolitan periphery can assess the knowledge complexity of the RCA sectors by comparing their product complexity index (PCI). Leveraging the existing knowledge bases and capabilities of the RCA sectors, entrepreneurs and policymakers can further search for the *structural holes* with close *knowledge proximity* in the *product space network* as potential fields to attract FDI inflows. Thereafter, they enhance the knowledge complexity and global connectivity of local industries, which further contributes to the overall industrial competitiveness of the metropolitan periphery.

Due to the exploratory nature of this research, we note that there are several limitations that leave open questions for further exploration. In our paper, we mostly concentrate on the functional transition of knowledge complexity industry from the metropolitan core to the periphery as well as FDI opportunities for international collaboration based on *knowledge proximity*. However, we haven't sufficiently addressed the indigenous process of industrial upgrading by taking into the contribution of non-manufacturing sectors, especially the emerging creative industries, which are underrepresented in this paradigm due to the lack of a coherent international classification and measurement standard. Regardless of the outflow of standardized jobs, many global metropolitans (e.g. Montréal, Barcelona, New York, Copenhagen) reshape their economic ecosystem in the patterns of "creative cities" and attracts the most qualified talents. They achieve global competitiveness not only measured by intensive manufacturing output, but also by their leadership in incubating creative ideas and novel business models (Bayliss, 2007, Cohendet *et al.*, 2010, Grandadam *et al.*, 2013). The building blocks of economic complexity theory do not fully capture this industrial evolution of emerging influence of the creative industries either. As single-case study, the contextual generality and longitudinal validity of conclusions are yet to be further tested by follow-up studies in different regional and industrial settings. In this sense, we call for alternative methods and multiple case studies of how manufacturing servitization and the emerging creative industries contribute to the sustainable development of the metropolitan periphery.

We also acknowledge that the ethical aspects of *product space network* in sustainable development regarding "green products" and "green jobs" are not sufficiently studied. Nonetheless these sustainability-related issues emerge as crucial subjects to redefine the industrial competitiveness and FDI opportunities. At the same time, we also see that the building blocks of the economic complexity theory have strong potential to explain the regional sustainable development directions. For instance, integrating the relatedness of RCA and *structural holes* with circular economy and green tech, a region's capabilities to develop green technology reflect its complex knowledge base in the *product space network*, and thereafter, trigger sustainable growth and more responsible policymaking (Bourdin & Nadou, 2020, Perruchas *et al.*, 2020, Veugelers, 2012). Future research on regional *economic complexity* can investigate how to incorporate sustainability issues and corporate social responsibility in enhancing a metropolitan periphery's industrial competitiveness and the potential FDI opportunities to support sustainable development.

References

Antonelli, C. 2004. Localized Product Innovation: the Role of Proximity in the Lancastrian Product Space. *Information Economics and Policy*, 16, p. 255-274. https://doi.org/10.1016/j.infoecopol.2003.10.002

Arikan, A. T. 2009. Interfirm Knowledge Exchanges and the Knowledge Creation Capability of Clusters. *Academy of Management Review*, 34, p. 658-676. https://doi.org/10.5465/amr.34.4.zok658

Asheim, B. T., Boschma, R. & Cooke, P. 2011. Constructing Regional Advantage: Platform Policies Based on Related Variety and Differentiated Knowledge Bases. *Regional Studies*, 45, p. 893-904. https://doi.org/10.1080/00343404.2010.543126

Balland, P.-A., Boschma, R., Crespo, J., *et al.* 2019. Smart Specialization Policy in the European Union: Relatedness, Knowledge Complexity and Regional Diversification. *Regional Studies*, 53, p. 1252-1268. https://doi.org/10.1080/00343404.2018.1437900

Balland, P.-A., Boschma, R. & Frenken, K. 2015. Proximity and Innovation: From Statics to Dynamics. *Regional Studies*, 49, p. 907-920. https://doi.org/10.1080/00343404.2014.883598

Balland, P.-A., Jara-Figueroa, C., Petralia, S. G., *et al.* 2020. Complex Economic Activities Concentrate in Large Cities. *Nature Human Behaviour*, 4, p. 248-254. https://doi.org/10.1038/s41562-019-0803-3

Balland, P.-A. & Rigby, D. 2017. The Geography of Complex Knowledge. *Economic Geography*, 93, p. 1-23. https://doi.org/10.1080/00130095.2016.1205947

Bathelt, H. & Li, P.-F. 2014. Global Cluster Networks—Foreign Direct Investment Flows from Canada to China. *Journal of Economic Geography*, 14, p. 45-71. https://doi.org/10.1093/jeg/lbt005

Bathelt, H. & Li, P. 2020. Processes of Building Cross-Border Knowledge Pipelines. *Research Policy*, 49, p. 103,928. https://doi.org/10.1016/j.respol.2020.103928

Bayliss, D. 2007. The Rise of the Creative City: Culture and Creativity in Copenhagen. *European Planning Studies*, 15, p. 889-903. https://doi.org/10.1080/09654310701356183

Berman, A., Marino, A. & Mudambi, R. 2020. The Global Connectivity of Regional Innovation Systems in Italy: A Core–Periphery Perspective. *Regional Studies*, 54, p. 677-691. https://doi.org/10.1080/00343404.2019.1672865

Boschma, R., Balland, P.-A. & Kogler, D. F. 2014. Relatedness and Technological Change in Cities: the Rise and Fall of Technological Knowledge in Us Metropolitan Areas from 1981 to 2010. *Industrial and Corporate Change*, 24, p. 223-250. https://doi.org/10.1093/icc/dtu012

Boschma, R., Minondo, A. & Navarro, M. 2013. The Emergence of New Industries at the Regional Level in Spain: A Proximity Approach Based on Product Relatedness. *Economic Geography*, 89, p. 29-51. https://doi.org/10.1111/j.1944-8287.2012.01170.x

Bourdin, S. & Nadou, F. 2020. The Role of a Local Authority as a Stakeholder Encouraging the Development of Biogas: A Study on Territorial Intermediation. *Journal of Environmental Management*, 258, 110,009. https://doi.org/10.1016/j.jenvman.2019.110009

Buckley, P. J., Glaister, K. W., Klijn, E., *et al.* 2009. Knowledge Accession and Knowledge Acquisition in Strategic Alliances: the Impact of Supplementary and Complementary Dimensions. *British Journal of Management*, 20, 598-609. https://doi.org/10.1111/j.1467-8551.2008.00607.x

Burt, R. S. 1992. *Structural Holes: the Social Structure of Competition,* Cambridge Harvard University Press.

Cano-Kollmann, M., Cantwell, J., Hannigan, T. J., *et al.* 2016. Knowledge Connectivity: An Agenda for Innovation Research in International Business. *Journal of International Business Studies*, 47, p. 255-262. https://doi.org/10.1057/jibs.2016.8

Cantwell, J. 2009. Location and the Multinational Enterprise. *Journal of International Business Studies*, 40, p. 35-41.

Cohendet, P., Grandadam, D. & Simon, L. 2010. The Anatomy of the Creative City. *Industry and Innovation*, 17, p. 91-111. https://doi.org/10.1080/13662710903573869

Colombelli, A., Paolucci, E. & Ughetto, E. 2019. Hierarchical and Relational Governance and the Life Cycle of Entrepreneurial Ecosystems. *Small Business Economics*, 52, p. 505-521. https://doi.org/10.1007/s11187-017-9957-4

Copus, A. K. 2001. From Core-Periphery to Polycentric Development: Concepts of Spatial and Aspatial Peripherality. *European Planning Studies*, 9, p. 539-552. https://doi.org/10.1080/713666491

Davies, B. & Maré, D. C. 2021. Relatedness, Complexity and Local Growth. *Regional Studies*, 55, p. 479-494. https://doi.org/10.1080/00343404.2020.1802418

Dawley, S. 2014. Creating New Paths? Offshore Wind, Policy Activism, and Peripheral Region Development. *Economic Geography*, 90, p. 91-112. https://doi.org/10.1111/ecge.12028

Delventhal, M. J., Kwon, E. & Parkhomenko, A. 2021. Jue Insight: How Do Cities Change When We Work from Home? *Journal of Urban Economics*, p. 103,331. https://doi.org/10.1016/j.jue.2021.103331

Fabrizio, K. R. 2009. Absorptive Capacity and the Search for Innovation. *Research Policy*, 38, p. 255-267. https://doi.org/10.1016/j.respol.2008.10.023

Feldman, M. 2005. The Locational Dynamics of the Us Biotech Industry: Knowledge Externalities and the Anchor Hypothesis. *Research and Technological Innovation.* Springer. https://doi.org/10.1007/3-7908-1658-2_9

Felzensztein, C., Gimmon, E. & Aqueveque, C. 2013. Entrepreneurship at the Periphery: Exploring Framework Conditions in Core and Peripheral Locations. *Entrepreneurship Theory and Practice*, 37, p. 815-835. https://doi.org/10.1111/j.1540-6520.2012.00515.x

Fischler, R. & Wolfe, J. 2000. Regional Restructuring in Montreal: An Historical Analysis. *Canadian Journal of Regional Science*, 23, p. 89-114.

Friedmann, J. 1966. Regional Development Policy: A Case Study of Venezuela.

Fritz, B. S. & Manduca, R. A. 2021. The Economic Complexity of Us Metropolitan Areas. *Regional Studies*, p. 1-12. https://doi.org/10.1080/00343404.2021.1884215

Gao, J., Jun, B., Pentland, A. S., *et al.* 2021. Spillovers across Industries and Regions in China's Regional Economic Diversification. *Regional Studies*, p. 1-16. https://doi.org/10.1080/00343404.2021.1883191

Gargiulo, M. & Benassi, M. 2000. Trapped in Your Own Net? Network Cohesion, Structural Holes, and the Adaptation of Social Capital. *Organization Science*, 11, p. 183-196. https://doi.org/10.1287/orsc.11.2.183.12514

Giroud, A. & Scott-Kennel, J. 2009. MNE Linkages in International Business: A Framework for Analysis. *International Business Review*, 18, p. 555-566. https://doi.org/10.1016/j.ibusrev.2009.07.004

Grandadam, D., Cohendet, P. & Simon, L. 2013. Places, Spaces and the Dynamics of Creativity: The Video Game Industry in Montreal. *Regional studies*, 47, p. 1701-1714. https://doi.org/10.1080/00343404.2012.699191

Hidalgo, C. A. 2021. Economic Complexity Theory and Applications. *Nature Reviews Physics*, p. 1-22. https://doi.org/10.1038/s42254-020-00275-1

Hidalgo, C. A. & Hausmann, R. 2009. The Building Blocks of Economic Complexity. *Proceedings of the National Academy of Sciences*, 106, p. 10570-10575. https://doi.org/10.1073/pnas.0900943106

Hidalgo, C. A., Klinger, B., Barab, *et al.* 2007. The Product Space Conditions the Development of Nations. *Science*, 317, p. 482-487. https://doi.org/10.1126/science.1144581

Iammarino, S. 2018. FDI and Regional Development Policy. *Journal of International Business Policy*, 1, p. 157-183. https://doi.org/10.1057/s42214-018-0012-1

Kang, M., Choi, Y., Kim, J., *et al.* 2020. Covid-19 Impact on City and Region: What's Next after Lockdown? *International Journal of Urban Sciences*, 24, p. 297-315. https://doi.org/10.1080/12265934.2020.1803107

Kano, L. 2018. Global Value Chain Governance: A Relational Perspective. *Journal of International Business Studies*, 49, p. 684-705. https://doi.org/10.1057/s41267-017-0086-8

Lorenzen, M., Mudambi, R. & Schotter, A. 2020. International Connectedness and Local Disconnectedness: MNE Strategy, City-Regions and Disruption. *Journal of International Business Studies*, 51, p. 1199-1222. https://doi.org/10.1057/s41267-020-00339-5

Mewes, L. & Broekel, T. 2020. Technological Complexity and Economic Growth of Regions. *Research Policy*, p. 104,156. https://doi.org/10.1016/j.respol.2020.104156

Neffke, F., Henning, M. & Boschma, R. 2011. How Do Regions Diversify over Time? Industry Relatedness and the Development of New Growth Paths in Regions. *Economic Geography*, 87, p. 237-265. https://doi.org/10.1111/j.1944-8287.2011.01121.x

Niosi, J. & Zhegu, M. 2005. Aerospace Clusters: Local or Global Knowledge Spillovers? *Industry and Innovation*, 12, p. 5-29. https://doi.org/10.1080/1366271042000339049

Pain, K. 2008. Examining "Core–Periphery" Relationships in a Global City-Region: The Case of London and South East England. *Regional Studies*, 42, p. 1161-1172. https://doi.org/10.1080/00343400701808857

Perri, A. & Peruffo, E. 2016. Knowledge Spillovers from FDI: A Critical Review from the International Business Perspective. *International Journal of Management Reviews*, 18, p. 3-27. https://doi.org/10.1111/ijmr.12054

Perruchas, F., Consoli, D. & Barbieri, N. 2020. Specialisation, Diversification and the Ladder of Green Technology Development. *Research Policy*, 49, p. 103,922. https://doi.org/10.1016/j.respol.2020.103922

Pierce, J. R. & Schott, P. K. 2012. A Concordance between Ten-Digit Us Harmonized System Codes and SIC/NAICS Product Classes and Industries. *Journal of Economic and Social Measurement*, 37, p. 61-96. https://doi.org/10.3233/JEM-2012-0351

Rodríguez-Pose, A. 2008. The Rise of the "City-Region" Concept and Its Development Policy Implications. *European Planning Studies*, 16, p. 1025-1046. https://doi.org/10.1080/09654310802315567

Santangelo, G. D. 2009. MNCs and Linkages Creation: Evidence from a Peripheral Area. *Journal of World Business*, 44, p. 192-205. https://doi.org/10.1016/j.jwb.2008.05.009

Scott, A. J. & Storper, M. 2005. *Pathways to Industrialization and Regional Development*, Routledge. https://doi.org/10.4324/9780203995549

Simoes, A. J. G. & Hidalgo, C. A. The Economic Complexity Observatory: An Analytical Tool for Understanding the Dynamics of Economic Development. Workshops at the twenty-fifth AAAI conference on artificial intelligence, 2011.

Turkina, E. & Van Assche, A. 2018. Global Connectedness and Local Innovation in Industrial Clusters. *Journal of International Business Studies*, 49, p. 706-728. https://doi.org/10.1057/s41267-018-0153-9

Turkina, E., Van Assche, A. & Doloreux, D. 2020. How Do Firms in Co-Located Clusters Interact? Evidence from Greater Montreal. *Journal of Economic Geography*. https://doi.org/10.1093/jeg/lbaa019

Turkina, E., Van Assche, A. & Kali, R. 2016. Structure and Evolution of Global Cluster Networks: Evidence from the Aerospace Industry. *Journal of Economic Geography*, 16, p. 1211-1234. https://doi.org/10.1093/jeg/lbw020

Veugelers, R. 2012. Which Policy Instruments to Induce Clean Innovating? *Research Policy*, 41, p. 1770-1778. https://doi.org/10.1016/j.respol.2012.06.012

Wang, Y. & Turkina, E. 2020. Economic Complexity, Product Space Network and Quebec's Global Competitiveness. *Canadian Journal of Administrative Sciences/Revue Canadienne des Sciences de l'Administration*, 37, p. 334-349. https://doi.org/10.1002/cjas.1555

Wang, Y. & Turkina, E. 2021. Quel Est Le Secret Des Villes Qui S'illustrent À L'échelle Mondiale? L'exemple De Laval. *The Conversation*. URL: https://theconversation.com/quel-est-le-secret-des-villes-qui-sillustrent-a-lechelle-mondiale-lexemple-de-laval-161043

APPENDIX

Calculation of complexity indices

1. Revealed comparative aAdvantage (RCA)

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*,

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

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*.
In our study, we replace the numerator as the ratio of the number of employment in municipality *m* in economic sector *p* (E_{mp}) over the total number of municipal employment, therefore, the adjusted RCA

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

2. Diversity index and ubiquity index

For the RCA matrix M_{cp} of global export of a given country, where the element m_{cp} presents if product *p* is an RCA sector country *c*

$$m_{cp} = \begin{cases} 1, & if\ RCA_{cp} \geq 1 \\ 0, & otherwise \end{cases}$$

The Diversity Index of country *c* equals to

$$Diversity\ (c) = k_{c,0} = \sum_{p=1}^{n} m_{cp}$$

Ubiquity Index of product *p* equals to

$$Ubiquity\ (p) = k_{p,0} = \sum_{c=1}^{n} m_{cp}$$

APPENDIX

Calculation of complexity indices

3. Product complexity index (PCI) and economic complexity Index *(ECI)*

Given two recursion expression indicating the relationship between Diversity Index ($k_{c,N}$) and Ubiquity Index ($k_{p,N}$):

$$k_{c,N} = \frac{1}{k_{c,0}} \sum_{p=1}^{n} m_{cp} \cdot k_{p,N-1}$$

$$k_{p,N} = \frac{1}{k_{p,0}} \sum_{p=1}^{n} m_{cp} \cdot k_{c,N-1}$$

Inserting the recursion expression of diversity $k_{c,N}$ into the recursion expression of ubiquity $k_{p,N}$, so that

$$k_{p,N} = \frac{1}{k_{p,0}} \sum_{c=1}^{n} m_{cp} \cdot \frac{1}{k_{c,0}} \sum_{p'=1}^{n} m_{cp'} \cdot k_{p,N-2}$$

$$= \sum_{p'=1}^{n} m_{cp'} \cdot k_{p',N-2} \cdot \sum \frac{m_{cp} m_{cp'}}{k_{c,0} k_{p,0}} \quad = \sum_{p'=1}^{n} k_{p'} \cdot \widetilde{M_{pp'}}, N-2$$

where,

$$\widetilde{M_{pp'}} = \sum_{p=1} \frac{m_{cp} m_{cp'}}{k_{c,0} k_{p,0}}$$

When $k_{p,N} = k_{p,N-2} = 1$, $\widetilde{M_{pp'}}$ is associated with the second largest eigenvalue that captures the largest among of amount of variance in the system.
Denote $\vec{Q}$ as the eigenvector of the second largest eigenvalue of $\widetilde{M_{pp'}}$ of a given country, and
$< \vec{Q} >$ represents the average of all countries in the datasets, a country's *Product Complexity Index (PCI)* can be calculated as

$$PCI = \frac{\vec{Q} - < \vec{Q} >}{stdev(\vec{Q})}$$

$stdev < \vec{Q} >$ stands for the standard deviation of $\vec{Q}$
Similarly, if we replace the product *p* with country *c*, and calculate

$$k_{c,N} = \sum_{c'=1}^{n} k_{c'} \cdot \widetilde{M_{cc}}, N-2 \qquad \widetilde{M_{cc'}} = \sum_{p=1}^{n} \frac{m_{cp} m_{c'p}}{k_{c,0} k_{p,0}}$$

a product's *Economic Complexity Index (ECI)* can be calculated as

$$ECI = \frac{\vec{K} - < \vec{K} >}{stdev(\vec{K})}$$

$\vec{K}$ is the eigenvector associated with the second largest eigenvalue of $\widetilde{M_{cc'}}$.

4. Proximity index

Let the Ubiquity Index of two categories of products (p,p') in the global export RCA matrix M_{cp} be ($k_{p,0}$,$k_{p'0}$).
The *Proximity Index* of product *p* and *p'* is calculated as:

$$\emptyset_{pp'} = \sum_{c=1}^{n} \frac{m_{cp} m_{cp'}}{\max\ (k_{p,0}, k_{p',0})}$$

Where m_{cp} presents if product *p* is an RCA sector country *c*

$$m_{cp} = \begin{cases} 1, & if\ RCA_{cp} \geq 1 \\ 0, & otherwise \end{cases}$$