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The effect of Knowledge sourcing by multi-plant firms on innovation growth in selected tech hubs in Canada

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Résumé

Ce mémoire explore le rôle des entreprises multi- sites dans la formation de l'innovation au sein des principaux centres technologiques canadiens, notamment Toronto, Ottawa, Waterloo, Montréal, Calgary et Vancouver. En utilisant une méthodologie quantitative descriptive, l'étude analyse les données de brevets de 2000 à 2019 pour examiner comment la provenance de connaissances des entreprises non locales impacte les écosystèmes d'innovation régionaux.

Les résultats révèlent des variations significatives entre les six centres. À Toronto, le plus grand centre technologique, les entreprises locales et non locales contribuent à un environnement technologique diversifié, avec un accent particulier sur les systèmes informatiques et les technologies de traitement des données. Ottawa, un centre hautement innovant, bénéficie de la forte présence d'entreprises multi- sites dans les télécommunications et la transmission d'informations numériques, ce qui conduit à des clusters technologiques spécialisés. En revanche, l'écosystème d'innovation de Waterloo montre une dépendance significative vis-à-vis des sources de connaissances externes fournies par les entreprises multi- sites, ce qui introduit un certain degré de vulnérabilité.

L'industrie technologique de Montréal, caractérisée par une grande diversité plutôt que par une spécialisation profonde, démontre une influence modérée mais significative des entreprises non locales, notamment dans les secteurs tels que l'aérospatiale et la transformation numérique. Cela contraste fortement avec Calgary, où le paysage technologique est principalement façonné par des entreprises locales. En tant que centre émergent, l'innovation à Calgary est notablement concentrée dans les technologies de forage terrestre, d'extraction minière et d'informatique, reflétant ses forces industrielles spécifiques. En ce qui a trait à Vancouver, la ville présente une trajectoire de croissance équilibrée avec un fort accent sur le traitement des données numériques et les technologies de communication, principalement soutenu par des entreprises locales.

La recherche conclut que les entreprises non locales introduisent effectivement des technologies distinctes dans les systèmes d'innovation locaux, leur impact variant en

fonction de la taille de la ville et des secteurs industriels. L'étude souligne l'importance de stratégies adaptées pour optimiser les interactions entre les entreprises locales et non locales afin de favoriser l'innovation et la croissance dans les différents centres technologiques.

Mots clés : entreprises multi-localisées, innovation, écosystèmes d'innovation régionaux, provenance des connaissances, analyse des données de brevets, clusters technologiques

Abstract

This thesis explores the role of multi-locational firms in shaping innovation within key Canadian technology hubs, including Toronto, Ottawa, Waterloo, Montreal, Calgary, and Vancouver. Using a descriptive quantitative methodology, the study analyzes patent data from 2000 to 2019 to examine how knowledge sourcing from non-local firms impacts regional innovation ecosystems.

The findings reveal significant variation across the six hubs. In Toronto, the largest tech hub, both local and non-local firms contribute to a diverse technological environment, with a particular focus on computing systems and data processing technologies. Ottawa, a highly innovative hub, benefits from the strong presence of multi-locational firms in telecommunications and digital information transmission, leading to specialized technological clusters. In contrast, Waterloo's innovation ecosystem exhibits a significant reliance on external knowledge sources provided by multi-locational firms, which introduces a degree of vulnerability.

Montreal's tech industry, characterized by its broad diversity rather than deep specialization, demonstrates a moderate yet significant influence of non-local firms, particularly in sectors such as aerospace and digital transformation. This contrasts sharply with Calgary, where the tech landscape is predominantly shaped by local firms. As an emerging hub, Calgary's innovation is notably concentrated in earth drilling, mining, and computer technologies, reflecting its specific industrial strengths. Transitioning to Vancouver, the city exhibits a balanced growth trajectory with a strong emphasis on digital data processing and communication technologies, driven primarily by local firms.

The research concludes that non-local firms do introduce distinct technologies into local innovation systems, with their impact varying depending on the city's size and industry sectors. The study underscores the importance of tailored strategies to optimize the interactions between local and non-local firms in fostering innovation and growth across different tech hubs.

Keywords : multi-locational firms, innovation, regional innovation ecosystems, knowledge sourcing, patent data analysis, technological clusters

Table of contents

List of Tables and Figures

List of Tables

List of Figures

Chapter1
Introduction

There has been significant growth and transformation within the technology sector in Canada, which encompasses a wide variety of subsectors. This evolution has been shaped by multiple factors, including advances in science and research and development and competition on global markets. Major investments, both public and private, have also been made to foster innovation in key sectors, such as artificial intelligence, information technology, and telecommunications (Doloreux & Frigon, 2022).

From the academic literature, it is well established that innovation as the mean of technology growth, is a key to the development of competitive advantages in firms and regional economic development (Wang et al., 2021). As an example, a study by OECD in 2000, benchmarking the US economy, has shown the importance of innovative information and communication technologies in the economic growth of OECD members, including Canada (OECD, 2000). In fact, it has been shown in a previous study that a significant link exists between innovation indicators and per capita economic growth in European countries, with this correlation being significant. As a result of this study, there is a greater awareness of the crucial role innovation plays in driving economies forward and prospering within a nation (Maradana et al., 2017).

Innovation in today's economic environment involves the creation and adoption of new ideas, technologies, and practices. A number of studies have underscored the importance of increasing innovation activity within existing industries as well as developing technological areas that are the basis of new technological sectors. As a result of this approach, new industries are formed and intersectoral structures are forged, emphasizing the dynamic role innovation has in shaping economic systems (Prokopenko et al., 2019).

By specializing in specific technological fields, regions are able to develop deep expertise in those fields, attract related firms and workers, and boost productivity. Ultimately, these dynamics can result in the formation of industrial clusters (Porter, 1998). As an example, the Silicon Valley has become synonymous with high-tech industries as a result of its intense focus on specific technology sectors, leading to the creation of innovation clusters

that attract talent, investment, and further technological advancement (Bresnahan et al., 2001). Canada is also host to multiple industrial clusters, or tech hubs, such as telecommunications in Ottawa or Aerospace in Montreal.

A large body of research has developed to identify the key determinants of the formation, development, and competitiveness of industrial clusters, notably in the field of economic geography (Frenken et al., 2015).

In addition to local-level factors, such as the presence of a 'local buzz' (Bathelt et al., 2004a; Storper & Venables, 2004), studies have shown that both the regional and the international levels can have a significant effect on the innovation performance of companies and enhance their competitiveness (Tödtling et al., 2012). As argued by Bathelt et al. (2004a), maintaining extra-local linkages allows regions and clusters to import diverse capabilities and maintain or augment innovation capabilities locally. Locally, scholars have also related the better innovative performance of clustered firms to knowledge spillovers, defined as the direct or indirect transfer of knowledge from one party to another. As a result, economic actors that are located in geographic clusters have more access to technological knowledge, which also contributes to better innovation performance (Gilbert et al., 2008).

As per external sources, being connected through the presence of multinational firms is one way to sustainably achieve external knowledge sourcing (Bathelt & Li, 2020). This is echoed by Cantwell (2017), who has discussed how multinational firms benefit from various localized knowledge pools and in turn influence the technological trajectory of their host locations.

Knowledge acquisition from external sources has thus been recognized as a key driver of innovation performance for firms and regions. Studies have demonstrated the benefits of sourcing external knowledge in order to leverage existing knowledge bases and innovate. The use of diverse sources of expertise and knowledge can help organizations to fuel innovation initiatives in order to boost productivity (Liao, 2018). Indeed, the complexity of innovation encourages firms to turn to external sources of knowledge, which the literature has shown to have a strong local character.

In this thesis, I explore more particularly the role of multi-locational organizations in tech hubs. As argued by Bathelt and Li (2020) and the recent literature on the agents of structural change by Neffke et al. (2018); Elekes et al. (2019), this type of organization is the most likely to inject diverse capabilities in local economies, and therefore to promote long-term economic development. Indeed, multi-locational firms can develop capabilities by sourcing knowledge from multiple locations simultaneously, and thus develop unique recombination of knowledge that span different knowledge spaces.

There are, however, multiple challenges. These firms must manage the intricate task of coordinating activities across multiple geographic locations, which presents challenges related to maintaining consistent communication, aligning diverse organizational cultures, and ensuring strategic coherence across all subsidiaries (Gertler, 2003; Phelps & Fuller, 2016). Despite the importance of transferring and integrating knowledge among different units of a multi-locational company, this can be challenging due to differences in local practices, technological infrastructure, and market environments (Bathelt et al., 2004a). As a result of addressing these challenges, firms and policymakers can improve knowledge flows, strengthen regional innovation systems, and enhance competitive advantage for regional hubs (Iammarino & McCann, 2013).

In this research project, I focus on Canadian firms with multiple locations, both within and outside Canada, that have at least one facility in the six key tech hubs: Toronto, Waterloo, Ottawa, Montreal, Vancouver, and Calgary. My primary data source is patent data, which I use to analyze how these firms' knowledge sourcing practices influence innovation growth in these hubs. Patent records constitute one of the main measures to capture knowledge-production activities in a location or a firm (Wang et al., 2021). Intellectual property rights including patents play a key role as a most significant impetus for innovation in knowledge-based economies (Cho & Kim, 2014). The integrated global economy also expands technological activities among firms which necessitates better intellectual property protections such as patents.

The core research question investigates whether nonlocal firms introduce distinct technologies into local innovation systems. By examining patent filings, I aim to map technological knowledge and identify the unique contributions of firms operating across

various locations. This study seeks to provide a comprehensive understanding of the innovation landscape in these tech hubs, highlighting how Canadian firms contribute to the introduction of new technologies and the enhancement of advanced technological capabilities.

This research tries to address a critical gap in the existing literature by exploring the role of multi-locational firms in driving innovation within specific regional hubs in Canada. While previous studies have examined the general impact of knowledge flows on innovation performance (Tödtling et al., 2012), or on the introduction of new products (Javorcik et al., 2018; Neffke et al., 2018), there is limited research that specifically investigates how multi-locational firms contribute to regional innovation. The ability of these firms to access and integrate diverse knowledge sources from various locations presents a unique opportunity for enhancing innovation capabilities in regional hubs. By focusing on Canadian tech hubs, this study provides valuable insights into how multi-locational firms introduce distinct technologies and practices into local innovation systems. As firms increasingly adopt global strategies while maintaining regional operations, understanding the dynamics of knowledge transfer and innovation in these contexts becomes essential. This research not only contributes to the academic discourse on innovation and economic geography but also provides practical implications for firms and policymakers aiming to strengthen regional innovation (Asheim & Isaksen, 2002; Cantwell, 2017).

Following in this study, a descriptive quantitative methodology is used to analyze the role played by multi-locational companies in driving innovation across the key Canadian technology hubs. The quantitative approach chosen allows for a systematic examination of patent data, providing objective insight into the patterns of innovation and knowledge flow within these regions. By utilizing descriptive statistics of patent data, the study provides a comprehensive overview of the technological landscape, highlighting the concentration of patents across various industries and cities. Using this methodology is particularly useful in identifying trends, comparing the innovation output of different regions, and assessing the impact of nonlocal firms on local innovation systems(Creswell & Creswell, 2017). This approach, however, has limitations, including the potential for

underreporting in patent filings and the exclusion of non-patented innovations. Despite these limitations, the descriptive quantitative methodology employed in this study offers valuable insights into the dynamics of innovation within Canadian tech hubs, forming a solid foundation for future research and policy development.

In summary, this research emphasizes the pivotal role of innovation and knowledge sourcing in advancing the growth and competitiveness of Canada's technology sector. By focusing on multi-locational firms and analyzing patent data from key Canadian tech hubs, the study seeks to reveal how these firms introduce new technologies and shape local innovation systems. This investigation addresses a notable gap in the literature and offers valuable insights into the regional innovation dynamics in Canada.

In the next chapter, we will explore the existing literature on innovation in multi-locational firms through the lens of economic geography, providing a framework for the subsequent analysis in the third chapter. The study's results will be presented in chapter 4, followed by discussion and conclusions in chapter 5. Ultimately, I aim to provide a comprehensive description of how multi-locational firms influence innovation within Canada's key technology hubs.

Chapter 2
Literature review

2.1 Modern economic landscape

Economic landscapes before globalization were distinguished by distinctive characteristics that were different from today's interconnected, interdependent global economy. The economy of the world operated in a more fragmented manner prior to the era of globalization, which gained significant momentum during the late 20th century. As a result of the globalization wave that began in the late 20th century, there has been an increase in interconnectedness and integration compared to pre-1913 (Bekaert & Mehl, 2019).

Today's business and economic landscape is marked by globalization, which has a significant impact on companies around the world. An analysis of globalization's effects on businesses and economies is presented in the paper "A Flat World, a Level Playing Field, a Small World After All, or None of the Above?" by Leamer (2007). This paper discusses that due to globalization, business strategies have changed, with companies now facing a more interconnected and competitive global market. With the integration of digitalization with globalization, changes have been further accelerated in the international business environment, which has led to new opportunities for innovative business environments. "The World is Flat" by Thomas L. Friedman which was the base of the mentioned paper, has been regarded as a seminal work that has had an influence on the discussion of globalization, international business, and the changing landscape of the economy as a whole. In Friedman's concept of a flat world, advancements in technology and communication have leveled playing fields for individuals and businesses worldwide, allowing greater connectivity and competition. However, scholars have presented dissenting views, which highlight the complexities, inequalities, and challenges that remain in the global business landscape. As a matter of fact, it has been argued that the world is not completely flat, but rather bumpy and semi globalized (Guillotin & Mangematin, 2015; Leamer, 2007).

This divergence in perspectives regarding the nature of the business landscape prompts an exploration of how businesses and regional economies adapt to the complexities and unevenness of the modern business world, considering factors such as global competition, diverse market conditions, and the impact of technological advancements on business operations. The transition towards a knowledge-based economy is a significant response to the changing dynamics of the modern business world (Mostafiz et al., 2019).

2.1.1 The Role of Knowledge in Modern Regional Economy

In the contemporary globalized economy, competition and economic growth rest in large part on the development, diffusion and use of non-ubiquitous knowledge (Malmberg & Maskell, 1999). In this model, innovation, entrepreneurship, and dynamism are emphasized, with knowledge serving as the central element of production. An economy based on knowledge plays a key role in driving economic progress and competitiveness as it results from the production, exchange, distribution, and use of knowledge at all level of the business cycle (Hadad, 2017). In fact, the shift away from traditional means of economic growth has caused countries to be more focused on mastering these aspects of economic growth and competitiveness in the global economy (Carstensen & Emmenegger, 2023).

There is a growing body of literature demonstrating that knowledge accumulation is closely related to innovation in a knowledge-based economy, which in turn leads to more complex production methods, specialized intermediate inputs, and a rise in an economy's technological intensity. It is important to recognize in the context of knowledge accumulation that acquiring new knowledge is not the only goal to be achieved, but also making use of existing knowledge so that it can be utilized to improve decision-making processes and drive innovation in an organization (Grant, 1996). It provides the foundation for knowledge management practices, leading to the transfer of knowledge within or outside of organizations and supporting the development of new ideas and solutions. (Legner et al., 2020). In fact, knowledge accumulation and knowledge transfer are interconnected processes crucial for organizational success and innovation. Knowledge accumulation and knowledge sharing constitute a symbiotic relationship: as organizations accumulate knowledge internally, they can share this knowledge with

external partners, fostering collaboration, innovation, and mutual growth. Sharing knowledge can also contribute to knowledge accumulation by bringing in external perspectives, new ideas, and diverse experiences that enrich the organization's knowledge base (F. Liu et al., 2020).

At the regional level too, knowledge and accumulated capabilities are believed to have an instrumental role in economic development. It is now well established that regions develop distinct knowledge and capability bases that shape their future trajectory of economic development (Kogler, 2013; Rigby, 2015). Knowledge is accumulated and diffused locally through the different economic and social linkages that bind actors together. The literature has also been clear, however, that external knowledge sourcing was also key in allowing regions to maintain a diverse knowledge base and avoid structural lock-ins (Martin, 2006). External knowledge sourcing can be undertaken by different actors, including individuals and their cross-border networks (Malmberg & Maskell, 1999), by organizations that engage in collaborations with extra-local actors (Trippl, 2009), but also by multilocational firms that mine knowledge from various locations and, to some extent, integrate and disseminate this knowledge in their cross-regional activities (Frigon, 2024; Frigon & Rigby, 2022).

2.1.2 The Role of Innovation in Modern Regional Economy

The creation and dissemination of knowledge are, by many, considered key competitive assets in the knowledge-intensive economy. As a consequence, a large literature has focused on innovation and its impacts on organizations and regions. The concept of the knowledge-intensive economy can be described as that of a economic system that is based on knowledge-intensive activities to produce goods and services. This is closely intertwined with the concept of innovation. A transition to a knowledge economy starts with understanding the significant role that science, technology, and innovation play in the advancement of global economic progress. The importance of innovation in the knowledge economy can be summed up by its ability to transform knowledge into a valuable resource and a key driver of economic growth (Podra et al., 2020).

The Organisation for Economic Co-operation and Development (OECD) defines innovation in Chapter 3 of the Oslo Manual 2018, an international standard for measuring

and understanding innovation, as "the implementation of a new or significantly improved product which can be good or service, process, marketing method, or organizational method in business practices, workplace organization, or external relations". This definition highlights that innovation extends beyond just introducing inventions, including improvements and adaptations of existing technologies, processes, and business models (OECD, 2018). Innovation, therefore, involves the practical application of a firm's accumulated knowledge, whether sourced internally or externally, for commercial or practical purposes. In other words, innovation is vital to the survival and success of firms and economies in today's rapidly evolving economic landscape. It is closely linked to value creation, which necessitates that businesses and economies continuously adapt and innovate to remain relevant and competitive. (Adak, 2015).

The influence of geography on innovation is a crucial factor that impacts the spatial distribution of knowledge creation, collaboration, and economic development. The dynamics of regional innovation growth is a complex process that involves multiple players, organizations, and resources within regional innovation systems. In their study, Huggins and Thompson (2015) emphasize the importance of networks of collaboration, knowledge exchange mechanisms, and cluster initiatives in driving regional innovation and competitiveness. The study investigates how regions may leverage their innovation potential to boost economic growth, knowledge production, and innovation diffusion. It emphasizes the importance of knowledge management, innovation policies, and cluster strategies in strengthening regional innovation ecosystems, which in turn support long-term economic development, job creation, and scientific progress inside regions. The study investigates the relationships between innovation, knowledge spillovers, and regional development, providing insights into how regional innovation systems shape the economic landscape. It emphasizes the importance of clusters in attracting investment, stimulating innovation, and establishing a conducive environment for knowledge-intensive enterprises (Huggins & Thompson, 2015).

The role of knowledge spillovers in the geography of innovation is also examined by Audretsch and Feldman (2004). They argue that spatial proximity among firms, research institutions, and other stakeholders facilitates the exchange of ideas and technological

advancements. This localized interaction, often observed in innovation clusters, allows for more effective dissemination of knowledge and supports the development of specialized industries within regions. By emphasizing the key role geographical concentration and proximity play in leveraging knowledge spillovers to boost regional competitiveness and innovation, the study provides valuable insight into how spatial distribution of knowledge resources influences regional economic dynamics.

Regional innovation is exemplified through a case study of China's Yangtze River Delta Region, where it is portrayed as a multidimensional phenomenon involving diverse actors, institutions, and resources collaborating to generate economic development and innovation. Zhang and Zhang's (2022) study focuses on the importance of networks in supporting innovation within the region, highlighting how stakeholders facilitate knowledge exchange, collaboration, and innovation distribution. The study investigate the geographical correlation impacts of regional innovation activities, specifically how network structures and spatial relationships influence innovation outcomes and regional competitiveness. Furthermore, the study look into collaborative mechanisms and knowledge innovation networks in the Yangtze River Delta urban agglomeration. The role of key cities, innovation resources, and knowledge spillovers in driving innovation across the area was also underlined which underscore the necessity of intra-regional knowledge cooperation for enhancing regional competitiveness (Zhang & Zhang, 2022).

Several other factors at the regional level have been shown to influence the development of innovation capabilities, in turn shaping the contemporary patterns of inter-regional economic inequality. In what follows, I will go over various perspectives that have been developed to understand these phenomena.

2.2 Economic Geography models

2.2.1 Agglomeration externalities and economics

The uneven distribution of economic activities has long been recognized by researchers in geography and economics. For instance, recent research using night lights by the Henderson et al. (2012) has been conducted over numerous grid cells across the globe, revealing significant patterns of economic development and disparities across regions.

The uneven distribution of economic activities, as observed through the intensity and spread of night lights across various grid cells, underscores the concentration of economic development in specific areas. This approach helps to visualize and quantify how economic activities are clustered geographically, often highlighting the stark contrasts between urban and rural areas or between developed and developing regions.

As a discipline, economic geography is not only concerned with the physical location of economic activities, however, but also with the relations, interactions, and flows within and between different spatial units (Rickard, 2020). In general, economic development in a region is closely linked to the distribution of economic activities. Optimal resource allocation and strategic positioning require an understanding of the factors influencing firm concentration in specific areas. Due to a combination of geographical, historical, and political factors, economic activities are distributed unequally in space. In shaping the economic landscape, several forces influence the spatial distribution of economic activities. Historical disparities in economic activity in different regions have been a key contributing factor to persistent spatial disparities. Furthermore, government policies and interventions, as well as urbanization and industrialization processes, play an important role in determining the spatial distribution of economic activities. It is possible for rapid urbanization to result in the concentration of economic activities in urban centers, creating spatial disparities between urban and rural areas.

These processes have been theorized differently depending on the specific disciplines researchers belong to. This section offers an overview of some of these approaches.

First, the spatial economy is inextricably linked to urbanization processes and the development of creative industries, emphasizing the importance of spatial factors in stimulating innovation and knowledge creation. In urban economics and economic geography, a concept known as agglomeration economics refers to the phenomenon in which economic activities concentrate in specific geographic areas, leading to greater productivity and efficiency. In this theory, there are significant advantages for industries and firms to be located in close proximity to one another, and this can lead to what is called agglomeration economies as a result (Kwok & Heo, 2019). These economies are

typically classified into two categories according to the scientific literatures such as Rosenthal and Strange (2004): those that are generated by specialization (MAR) and those that are generated by diversity (Jacobs).

The first theory, MAR (Marshall-Arrow-Romer), is a theory that focuses on the positive externalities that arise from concentrating similar or related economic activities in a particular geographic area. In this theory, it is proposed that when firms of the same industry or sector cluster together in a particular locality, they will be able to benefit from knowledge spillovers, input sharing, and labor market pooling. MAR hypothesis proposes the notion that when similar industries co-locate, there are synergies and efficiencies that can be gained, which might result in a boost in productivity and technological improvements. (Sahdev, 2016).

The first externality to discuss based on MAR theory is the knowledge spillovers. This concept refers to the diffusion of knowledge or information from one entity to another within a geographical area that can create positive benefits. As a result of this phenomena, firms who are located close to one another and that are linked by common technological bases or sectoral characteristics benefit from sharing ideas, technologies, and innovations, ultimately enhancing their overall performance. In fact, Knowledge-intensive activities concentrated in a specific area can lead to regional innovation systems that stimulate creativity, entrepreneurship, and technological advancement. The sharing of knowledge not only enhances the innovation capacity of the region, but also contributes to the resilience and adaptability of the local economy (Mura & Ključnikov, 2018; Rosenthal & Strange, 2004).

The second externality discussed in the MAR theory is the input sharing. Shared inputs, often referred to as economies of scale, refer to the cost advantages that can be achieved by firms when they share resources, infrastructure, and inputs while decrease the transportation costs as soon as they are located close to one another. The assumption is that in agglomeration economies, the sharing of inputs contributes to substantial productivity gains and increases the level of innovation among firms (Melo & Graham, 2018; Rosenthal & Strange, 2004).

The third externality to discuss based on MAR theory is labor market pooling. This concept refers to the concentration of labor forces in specific regions, leading to increased efficiency and productivity through the sharing of skills, expertise, and knowledge among workers. In the context of agglomeration, labor market pooling operates as a mechanism that enables firms to access a diverse talent pool, fostering innovation and specialization within industries. By clustering industries and firms in specific locations, agglomeration facilitates the formation of labor pools that enable the efficient matching of skills with job requirements, leading to increased productivity and innovation (Rigby & Brown, 2015).

The second theory which is urbanization externalities, based on the work of Jane Jacobs, emphasize the important role that diverse and interconnected urban environments play in promoting innovation and economic prosperity that are associated with urbanization. In the view of Jacobs, cities with a mix of industries and a vibrant urban fabric facilitate knowledge spillovers and an increase in creativity. In urban areas, different types of people and different skill sets are brought together, creating a hub of diversity, which, in turn, stimulates innovation and entrepreneurship in these areas. Jacobs' theory emphasizes the importance of urban agglomerations in the development of a dynamic environment in which ideas are free to flow, which is conducive to the development of new technologies and industries (Ma et al., 2019).

Agglomeration can also be studied through heterogeneous actors. The authors, Behrens and Robert-Nicoud (2015), explore agglomeration theory from the perspective of heterogeneous actors, in particular how agglomerated regions are shaped by a variety of types of people and firms interacting to generate specific economic outcomes in the regions. According to the authors, sorting mechanisms, productivity gains, and economies of agglomeration all play significant roles in shaping the spatial distribution of economic activities in an area (Behrens & Robert-Nicoud, 2015).

One of the key aspects of productivity differentials between regions is the effect of agglomeration on regional productivity differences. Based on the theory, larger cities have a higher skill reward than smaller ones because of agglomeration effects, where the concentration of economic activities leads to a higher level of productivity and specialization in the economy. As a result of this spatial equilibrium theory, we can

uncover the mechanisms through which agglomeration influences economic outcomes within different urban centers, offering insight into the mechanisms by which agglomeration fosters adaptation across different urban centers (Davis & Dingel, 2019).

Regarding the shaping of agglomeration through concentration of economic activities, the spatial concentration of business activities, particularly complex business operations, is mostly observed in large cities. Balland et al. (2020) investigate the spatial distribution of economic activities, highlighting the prevalence of complex economic activity in big urban regions. The study states that the presence of multiple networks in metropolitan regions helps to cluster economic activity, especially those that are knowledge-intensive and technologically advanced. Large cities, with their dense networks of businesses, institutions, and skilled workers, provide an ideal environment for the growth and concentration of complex economic activities. This, in return, emphasizes the crucial function of large cities as hubs of economic complexity and innovation, evolving the landscape of economic activities.

While agglomerations can theoretically provide advantages to all firms and industries, the extent of these benefits can vary significantly. According to research by Rigby and Brown (2015), multi-plant or multi-locational companies are particularly well positioned to take advantage of the numerous benefits of agglomerated environments. These firms benefit from the ability to strategically establish themselves in various regions, each offering distinct benefits such as industry-specific resources, specialized labor, and enhanced knowledge spillovers. This strategic positioning allows multi-locational firms to optimize their operations and innovation capabilities. Additionally, their study highlights that firms in high-tech and knowledge-intensive industries benefit the most from agglomeration due to their reliance on specialized skills and resources, which are more readily available in clustered settings (Rigby & Brown, 2015).

2.2.2 Industrial Cluster

The agenda regarding the co-location of firms was also discussed by a leading scholar in the field of strategic management, Michael Porter, where he argued that the co-location of related firms can create positive externalities which bring competitive advantages for firms. Porter argues that while globalization increases opportunities for firms, competitive

advantage usually results from local conditions and interactions. According to him, clusters, which are geographical concentrations of businesses and institutions with a strong level of collaboration and knowledge sharing, drive innovation and productivity. As a result of shared resources, infrastructure, and specialized labor, firms located in a cluster are able to adapt more readily to global changes. Porter emphasizes how successful clusters can attract investment and talent, resulting in their higher economic impact. Clusters can enhance their global competitiveness by leveraging local advantages to achieve greater innovation and efficiency. (Porter, 2000). As a framework, the Diamond Model developed by Porter has significantly influenced the understanding of competitiveness and economic development. This model emphasizes the interconnectedness of various factors that contribute to a nation's competitive advantage in specific industries. One key aspect of the Diamond Model is its relationship to clusters. The Diamond Model underscores the significance of clusters as dynamic entities that influence the competitive advantage of firms operating within them (Porter, 1998).

Despite the fact that some scholars view clusters as a panacea to enhance competitiveness and innovation, some criticize them as conceptually shaky and difficult to define. Taking into account this dichotomy highlights the difficulty of understanding clusters' role in economic development as well as the challenges that come with implementing cluster development in practice. In a study by Martin and Sunley (2003), the authors explore the ways in which clusters can drive innovation and economic growth through collaboration between businesses, institutions, and governments. As they argue, clusters can be beneficial, but are often applied inconsistently, posing challenges to implementation and measurement (Martin & Sunley, 2003).

Based on previous studies, firms seek to operate in clusters for a variety of reasons. Clusters create an atmosphere that encourages new business formation and growth by providing a number of advantages. For starters, clusters reduce enterprises' entrance costs, making it less difficult for emerging companies to establish themselves in a supportive network. Second, being located in a cluster increases enterprises' market opportunities by providing access to a group of potential consumers and partners. Third, clusters foster an environment conducive to innovation, allowing businesses to benefit from localized

resources and knowledge spillovers to create innovative goods and services. Lastly, businesses located in clusters could advantage from the existence of alternative successful regional businesses, lowering perceived entry risks and creating chances for collaboration and growth (Delgado et al., 2010).

Concentrating economic actors in a region has the potential to bring many benefits, both in terms of innovation and economic development. Knorringa et al. (2016) suggest that when economic actors, such as firms, universities, research institutions, and governments, cluster together, they can create a dynamic ecosystem that fosters innovation between them. As a result of this clustering effect, actors can collaborate more effectively, learn from each other, and share resources among themselves, which are essential aspects of driving innovation processes. In the context of an economy where economic actors are positioned close to each other, they are able to leverage each other's expertise, capabilities, and networks to produce new ideas, products, and services, thus driving economic growth and enhancing competitiveness (Sørensen & Torfing, 2016). Working together in a clustered environment enables economic actors to pool their resources, including capital, technology, and expert knowledge, in order to drive innovation initiatives that benefit the entire ecosystem at the same time (Meagher, 2017).

The most well-known cluster in association with innovation in a knowledge-based economies can be a technology hub, mostly known as tech hubs. A tech hub can be defined as " the integration of innovation laboratories for research and development (R&D) projects in a single physical space and features partnerships between public and private companies and institutions, as well as incubators for technology companies, environments conducive to innovation projects and innovation pre-incubators" (Vitorino Filho & Moori, 2018).Tech clusters, for instance Silicon Valley as the most famous one, have emerged as critical hubs for promoting innovation, increasing company competitiveness, and driving economic growth. These clusters bring together a concentration of high-tech companies, research institutions, and skilled labor, creating an ideal environment for collaboration and knowledge sharing. The proximity of these entities within a cluster encourages frequent communication and collaboration, resulting in greater innovation efficiency.

High-tech clusters benefit from the worldwide exchange of knowledge, people, and finance, which is critical to their growth and success (Kerr & Robert-Nicoud, 2020).

Tech clusters in Canada have played an important role in promoting innovation, entrepreneurship, and economic growth. Studies on Canadian industrial clusters have shown that start-ups with less overall assets and strong human resources benefit greatly from local specialization and labor pooling within these clusters (Li et al., 2019). Furthermore, as seen in the U.S., prominent Canadian tech clusters also have a significant representation of immigrant entrepreneurs, particularly those in the high-tech sector. (Kerr & Kerr, 2018).

According to research, knowledge-based enterprises in Canada benefit from clustering, co-location, and technological and innovation spillover inside high-tech clusters. However, the influence of clusters on business growth in Canada has been found to be very localized, with only minor benefits on firm survival, notably in the IT industry. Despite this, Canadian tech clusters serve an important role in promoting information sharing, collaboration, and innovation among high-tech enterprises (Nilsson et al., 2019; Zandiatashbar & Hamidi, 2021). These clusters create an environment for businesses to improve their operational capabilities, obtain a competitive edge, and drive innovation by implementing technology such as business intelligence systems (Yiu et al., 2020).

Knowledge creation inside a cluster is a dynamic interaction of multiple factors that all contribute to the generation of new ideas, insights, and inventions. Recent research has emphasized the significance of knowledge management techniques, intellectual capital, and company performance in promoting knowledge production processes within clusters (Hussinki et al., 2017). The process of knowledge creation inside a cluster is influenced by the value creation mechanisms used in policy-driven cluster efforts, emphasising the importance of understanding how value is generated for cluster members. Furthermore, the function of leadership, information sharing, and innovation in knowledge production has been studied, emphasizing the importance of both tacit and explicit knowledge exchange in producing new insights and ideas within clusters (Lei et al., 2021).

Research has also looked into the dynamics of technological competence development inside cluster organizations, emphasizing the importance of interpersonal interactions,

social networks, and external learning mechanisms in promoting knowledge production processes. Studies has also provided methodologies for assessing knowledge transfer efficiency within innovation clusters, underlining the relevance of effective knowledge dissemination and sharing channels in fostering cluster-wide innovation (Zhang & Xu, 2022).

Technological innovation clusters are dynamic environments in which knowledge transmission is critical to driving progress and encouraging innovation. Fioravanti et al. (2021) present a comprehensive examination of information transmission within these clusters, offering light on how knowledge moves and is used. By focusing on knowledge diffusion and absorption methods, the study contributes to a better understanding of how technical improvements are fostered inside innovation clusters. This study emphasises the importance of measuring knowledge transfer efficiency based on many elements affecting the process, such as knowledge transfer subject traits, content, environment, and coordinating behaviour. Absorptive capacity emerges as an important notion for understanding knowledge transfer in technological innovation clusters. According to this study, absorptive capacity allows organizations to value, assimilate, and utilize new knowledge, hence increasing their innovation capacities. The inevitability of information spillover in clusters, as well as the challenges of knowledge transfer, are discussed in further detail, with an emphasis on absorptive capacity as an analytical framework. The research gives insights into improving innovation undertakings through effective knowledge transfer practices inside technological innovation clusters by investigating individual knowledge transfer mechanisms and testing them using agent-based technologies (Fioravanti et al., 2021).

The study conducted by Bathelt and colleagues (2004) also delves into the mechanisms of knowledge generation within clusters, with a specific emphasis on the notions of "local buzz" and "global pipelines." The term "local buzz" refers to the informal and spontaneous exchange of knowledge in a local or regional setting. "Global pipelines," by contrast, represent formal, structured, and planned links that facilitate the flow of knowledge external to a region. The study shows that both local buzz and global pipelines provide distinct advantages for organizations engaged in innovation and knowledge generation.

Local buzz, defined by wide face-to-face interactions inside a spatially concentrated cluster, enables the rapid transmission of knowledge and interactive learning among nearby participants. Global pipelines, on the other hand, include external connections that reach beyond the immediate cluster and contribute to the acquisition of varied information and resources, promoting distinct processes of knowledge distribution and creation through interactive learning and observation (Zhu et al., 2018). The study emphasizes the need of combining local buzz with global pipelines for cluster innovation dynamics, as they foster a dynamic process of knowledge generation that is critical for understanding a cluster's development path. Furthermore, the research demonstrates that establishing and maintaining external linkages are vital complements to the local buzz generated within clustered hubs where innovative projects are concentrated (Bathelt et al., 2004b).

2.2.3 Importance of knowledge sourcing locally and outside the region

The study by Bathelt et al.(2004) stresses the importance of carefully examining internal as well as external dynamics to understand the development trajectory of regions and clusters. It shows that both local buzz and global pipelines provide distinct advantages for organizations engaged in innovation and knowledge generation.

Other studies have shown that maintaining external linkages can positively contribute regional economic development and the performance of industrial clusters. For instance, in recent empirical studies, Wang (2015) shows how enterprises increasingly rely on external knowledge to improve their innovative performance. This reliance on external knowledge sources is further strengthened by Scalera et al. (2018), who investigate the spatial dimensions of knowledge connection within and across home country boundaries. Understanding the geography of knowledge sourcing requires distinguishing between sourcing information within one's own country and beyond borders. Furthermore, Terjesen and Patel (2015) investigated the relationship between search breadth and depth in information acquisition for innovation outcomes. They discovered that, whereas search breadth is inversely correlated with process innovation outcomes, search depth is positively associated. This underlines the significance of geography in knowledge sourcing strategies, as businesses navigate the breadth and depth of external knowledge channels to promote innovation (Scalera et al., 2018; Terjesen & Patel, 2015; Wang, 2015)

Grillitsch and Trippl (2014) also emphasized the importance of geography in knowledge sourcing through the combination of knowledge from various sources, channels, and geographical scales. Their study emphasizes the importance of combining knowledge gathered from multiple partners at different spatial levels and through different channels in order to effectively promote innovation and knowledge production. It emphasizes the significance of various knowledge combinations for improving company performance and promoting innovation. By uncovering that most information combinations include international, regional, and national levels, the study underlines the need of mixing knowledge from several geographical scales for boosting innovation. In addition, the study's findings shed light on how organizations use spillovers and other channels to gain knowledge related to innovation, highlighting the complex character of knowledge acquisition and exchange. (Grillitsch & Trippl, 2014).

2.3 Multi-locational firms

A recent literature reexplores the role of internal and external factors in shaping regional economic development by examining the role of different types of agents in triggering diversification and supporting structural change (or adaptation). Studies by Neffke et al. (2018), Elekes et al. (2019) and Kogler et al. (2023), among others, have found that nonlocal firms played the most important role in introducing novel capabilities in regions. The relationship between FDI and development will therefore be reviewed in this section.

2.3.1 Firms FDI Evolution

In the history of foreign direct investment (FDI) strategies, firms have historically progressively relocated their value chain activities outside of their home countries, followed by foreign subsidiaries taking on more strategic roles within the organization, and finally, set up headquarters or divisional offices abroad as a part of their Foreign Direct Investment (FDI) strategies. Through the transfer of knowledge via the inward transplantation of firms into these countries, foreign direct investment has been recognized for its role in the introduction of new technological and industrial pathways on the local scale (Trippl et al., 2017).

As a result of recent changes in the landscape of FDI, a more nuanced understanding of knowledge acquisition has been developed in different geographical locations. Knowledge spillovers and absorptive capacity are now being increasingly valued by companies when it comes to driving local firm innovation through FDI. There has been a growing interest in the concept of knowledge spillovers from FDI, which focuses on how domestic firms can benefit from the knowledge that is brought in by foreign investors. It has been shown in research that firms operating in regions with robust intellectual property rights protection, market development, and international openness are better equipped to leverage spillovers and enhance productivity (Yi et al., 2015).

Over time, the motivations for firms to undertake foreign direct investments (FDIs) have changed, as global economic landscapes and business strategies have evolved as well. There is an emerging trend where corporations are increasingly seeking out specialized knowledge assets as an important factor in driving FDI rather than the traditional motivations of seeking foreign markets, cost efficiency, and resources. The shift in motivation reflects the changing nature of global competition and the increasing importance of intangible assets in driving firm performance (Qian & Cao, 2019).

Cantwell's (2017) research on the geography of knowledge sourcing further supports the above trend, demonstrating that multinational enterprises (MNEs) are strategically positioning their operations in regions with high concentrations of specialized expertise and technological capabilities. This strategic approach underscores a broader reorientation towards leveraging localized knowledge assets to foster innovation and maintain competitive advantage. By focusing on physical proximity to cutting-edge knowledge and technology, MNEs enhance their ability to integrate and capitalize on valuable information, thereby driving their global innovation efforts and adapting to the rapidly evolving business environment (Cantwell & Mudambi, 2011). This strategic emphasis on geographic dispersion is mirrored in the findings of Frigon and Rigby (2023); Frigon and Rigby (2024), who explore how multi-plant firms across Europe further optimize their knowledge sourcing by leveraging the unique strengths of various regional settings. Their study highlights that these firms benefit from their ability to access a variety of specialized

knowledge pools and technological advancements concentrated in different regions across Europe and the US (Frigon & Rigby, 2023; Frigon & Rigby, 2024).

2.3.2 Knowledge sourcing by multi locational firms

The collection of research on the production and exchange of knowledge in multi-locational enterprises has drawn more attention recently. Studies have looked at the ways in which information is created and shared, with a focus on how geographical locations may facilitate or impede these processes, emphasizing the importance of intra-firm knowledge flows between locations and how they affect innovation performance (Yousaf et al., 2022).

The concept of knowledge sourcing refers to the process through which firms acquire external knowledge to support their innovation and operational activities. In the context of multi-plant firms, knowledge sourcing involves obtaining knowledge from various internal and external sources to enhance the firm's overall capabilities and competitiveness. These sources may include other plants in the same organization, partners outside the organization, international networks, and local knowledge ecosystems. The results of a study with tile " Knowledge sourcing by multi-plant firms in Europe" by Frigon and Rigby (2023) explain the complexity and the importance of the knowledge sourcing in this type of firms. First, the paper demonstrated that multi-plant businesses generate various types of knowledge in various places which highlights the importance of knowledge sharing between different plants. Secondly, the study discussed that patents created within a company's facilities are connected to the knowledge bases of the areas in which they conduct business. Considering the fact that the use of patents as an indicator of innovation and knowledge production has been extensively studied (Link & Hasselt, 2019), the second result of this study highlights the importance of geographical knowledge sourcing in improving innovation. Lastly the paper discussed the fact that higher number of plants for a multi-locational firm equates with more complex knowledge production (Frigon & Rigby, 2023).

To understand the importance of knowledge management in respect to the economy of firms, The article "The explicit economics of knowledge codification and tacitness" goes deeply into the complex economic elements of knowledge codification and tacitness,

providing a full assessment of the explicit economics underlying these ideas. The study gives useful insights into the economic consequences of knowledge management systems by investigating the constraints and benefits of explicit and tacit knowledge within organizational contexts, with a particular emphasis on codification and personalization tactics. The emphasis on understanding the economic components of knowledge management, particularly the transition of tacit knowledge into explicit forms, highlights the significance of such understandings in improving organizational performance. This study makes a substantial contribution to the field by investigating the economic foundations of knowledge management techniques and providing interesting thoughts on how these tactics affect organization. Furthermore, Knowledge management and geography are intricately linked when considering firms' economies. The geographical location of a firm plays a crucial role in shaping its knowledge dynamics and economic performance. Knowledge-intensive activities often benefit from being located in regions with high knowledge intensity due to the presence of knowledge spillovers and access to local expertise. In fact, studies by Inoue et al. (2017), Buzard et al. (2020), Jang et al. (2009), Kang and Dall'Erba (2016), and Murata et al. (2014) highlight the importance of geographic proximity and spatial clustering as another important factor in promoting knowledge spillovers. These studies emphasize the importance of localized knowledge spillovers in economic undertakings by investigating both local and long-distance knowledge diffusion in regional knowledge generation. They emphasize the critical role of regional agglomeration and spatial connectedness among firms in supporting information interchange and innovation, as well as the explicit economics of knowledge codification and tacitness (Cowan, 2000).

It is also important to note that multi-locational firms, by operating in diverse locations, have access to a wide range of knowledge sources that can significantly impact their innovation processes and outcomes. Asheim and Isaksen (2002) investigate the dynamics of these firms in regional innovation systems, specifically how they combine local "sticky" information with global "ubiquitous" knowledge. "Sticky" information refers to tacit knowledge that is deeply rooted in local contexts, making it challenging to transfer outside of the region. This type of knowledge is often specific to a particular area, industry, or community, and its transferability is limited due to its context-specific nature. On the

other hand, "ubiquitous" knowledge is globally available and easily accessible across different regions and industries. This type of knowledge is more codified and can be disseminated widely, allowing for broader utilization and application in various contexts The study underlines the necessity of integrating various sources of knowledge to promote regional innovation and economic success. The findings emphasize the importance of combining local knowledge assets with global insights to improve innovation capabilities. The study emphasizes the critical role of regional players, institutions, and policies in facilitating the integration of various information sources to foster innovation and regional competitiveness (Asheim & Isaksen, 2002).

Understanding how knowledge flows through firms networks is also essential for innovation development. Huggins and Johnston (2010) have explored the complex dynamics of knowledge transfer within inter-firm networks in detail. Their study discusses that the higher number of investments in developing inter-firm and external knowledge networks can positively affect the level of innovation in the firm. Given the connection between a firm's size and its involvement in capital investments and knowledge networks, we may also view a firm's size as a contributing factor to its level of innovation. Their paper emphasizes the significance of the resource-based view of the firm and inter-firm network theory in understanding the dual requirement for firms to form and manage alliances for knowledge creation while also possessing internal capabilities for efficient knowledge exploitation within innovation. Furthermore, the study of spatial proximity's impact on inter-organizational relationships and network development shows its critical role in shaping collaborative and competitive interactions. This study found that organizations that rely heavily on local knowledge sourcing are more likely to use social networks as a knowledge source, highlighting the importance of geographical proximity to foster knowledge flow within these networks. The results also imply that managing knowledge partnerships requires more resources compared to generic knowledge sourcing which can create issues for smaller companies as it is harder for them to foster knowledge partnership. In fact, as startups develop, they may gain more access to external knowledge for exploitation, but their willingness and ability to learn from informal sources may decline. This fact proves that external learning mechanisms may change as firms grow (Huggins & Johnston, 2010).

The complex dynamics of knowledge transfer have implications for regional development more broadly. As an illustration, a study by Andersson and Karlsson (2007) have shown that knowledge accessibility is a significant factor in driving regional economic development. This study highlights that regions offer not only externalities and unintentional diffusion of knowledge known as knowledge spillovers, but also localized market-mediated mechanisms. This mechanism is defined as how markets within an area operate as channels for the flow of knowledge, allowing firms to effectively obtain and utilize knowledge to boost their productivity and competitiveness. Furthermore, the research reveals that extra-regional knowledge accessibility can be essential for minimizing concerns regarding local stakeholders' lock-in effects, where stakeholders in a particular region become entrenched in existing practices or systems, limiting their ability to adapt to new technologies, ideas, or market conditions. This fact emphasize the potential benefits of expanded knowledge access beyond regional boundaries (Ghinoi et al., 2021). These findings emphasize the multidimensional character of knowledge accessibility and its impact on regional economies (Andersson & Karlsson, 2007).

It has also been argued that multi-locational corporations strategically prefer clusters towards seeking their knowledge investment process. According to research, organizations with larger financial resources and stronger development and acquisition opportunities are more likely to choose clustering. Multi-locational companies strategically structure their activities in clusters to take advantage of the value of innovations made there, using processes such as technology distance, value internalization, and control. The existence of enterprises in different clusters can have an impact on their overall technological performance, albeit this link has not been fully explored. Firms within clusters typically have lower debt ratios, higher cash balances, and more transactions than those outside of clusters (Almazán et al., 2010).

2.3.3 Technological innovation and competitiveness in multi-locational firms

The study of the impact of multiple knowledge networks on innovation in foreign operations emphasizes the importance of diverse knowledge sources in generating innovation inside multinational corporations. Previous research has shown that interactions across multiple knowledge networks can have a significant impact on learning and innovation outcomes, with different combinations of high and low embeddedness across parent, host-country, and third-country knowledge networks influencing the type of innovation achieved, whether incremental or radical. This highlights the intricate interaction of many information sources in affecting innovation results within multinational corporations (MNCs). By carefully controlling knowledge flows across these networks, organizations can strengthen their innovation capacities and promote competitiveness in global markets, demonstrating the essential importance of knowledge in encouraging innovation. Furthermore, the complexities of knowledge networks in the context of overseas operations, as well as how interactions across these networks impact organizations' global innovation capacities and outcomes has been discussed in previous research. The findings of these studies underscore the importance of organizations leveraging varied information sources and skillfully navigating extensive knowledge networks in order to foster innovation and preserve competitiveness in international operations (Pittaway et al., 2004).

In order to be successful in international business, innovation must be part of the process. This link is crucial to understanding technical innovation and enhancing competitiveness in global marketplaces. A study by Cantwell (2017) presents a roadmap for firms that are operating in multiple locations on how to effectively use innovation as a tool for achieving international success. To begin, businesses should prioritize building an innovative culture within their organizations, supporting employee creativity and idea generation. This can be supplemented by forming cross-functional teams with various expertise to drive innovation efforts. Second, organizations must prioritize constant learning and knowledge acquisition, both internally through R&D operations and outside through collaborations with external partners and stakeholders. Firms may fuel innovation by using internal R&D skills and external knowledge networks, providing access to a larger pool of ideas and technology. Furthermore, businesses should invest in technology

and digital tools to speed innovation processes and improve cooperation among worldwide teams (Cantwell, 2017). Innovation in multinational companies (MNEs) entails complex processes of strategically allocating resources and transferring knowledge between culturally different subsidiaries. Dellestrand and Kappen (2011) emphasize the need of considering cultural issues when allocating resources for innovation transfer projects within MNEs. They note that significant cultural variations across subsidiaries at the subnational level can inhibit innovation transfer, emphasizing the importance of integrating resource allocation techniques with cultural concerns in order to support successful innovation transfer. The study looks into how MNE headquarters overcome the problems of transferring innovation across culturally varied subsidiaries, offering light on the constraints and opportunities connected with allocating resources for innovation projects in a global context. In other words, the study stress the importance of considering cultural factors in resource allocation decisions for innovation transfer projects within MNEs, emphasizing the need to align resource allocation strategies with cultural considerations to facilitate successful innovation transfer (Dellestrand & Kappen, 2011).

As mentioned, to ensure survival, firms must embrace innovation; however, managing this innovation effectively across diverse locations poses a significant challenge. In the context of multinational enterprises (MNEs), the management of innovation across different locations involves a variety of factors, such as internationalization, subsidiary operations, knowledge transfer, and strategic decision-making. Internationalization is vital for shaping the innovation performance of multinational enterprises (MNEs). By expanding globally, MNEs diversify the flow of ideas and knowledge within their organization, thereby fostering innovation both at the local and parent company levels (Wu et al., 2016). Research by Nuruzzaman et al. (2018) also highlights the pivotal role of subsidiary operations in driving innovation within multinational enterprises (MNEs). Foreign subsidiaries are increasingly seen as essential contributors to innovation and overall performance enhancement. Their capacity to innovate is crucial for MNEs to adapt to local market conditions, leverage diverse institutional environments, and maintain competitiveness in a rapidly evolving global landscape (Nuruzzaman et al., 2018). The transfer of knowledge within MNEs is another critical aspect of innovation management. Within MNEs, effective knowledge transfer mechanisms, such as human resource

management practices and training and development programs, facilitate the flow of tacit and explicit knowledge. Knowledge transfer positively impacts subsidiary innovation performance, highlighting how it is important to leverage internal expertise in order to achieve innovation success (Xie et al., 2022).

2.3.4 Multi-locational firms and regional development

The multi-locational firms play a key role in regional economic diversification. A study by Neffke et al. (2018) has proven that through broader access to external knowledge and resources, multi-locational companies have the potential to transform regional economies in a significant way. This study also emphasizes the importance of these firms in creating spillover effects that benefit local firms. Collaboration between multi-locational firms and local companies can facilitate the diffusion of new technologies and practices, leading to the development of a region as a whole. Elekes et al. (2019) also argue that multi-locational firms, particularly foreign-owned ones, play a critical role in regional development by introducing new industries, advanced technologies, and innovative practices into local economies, as well as providing access to global networks and diverse knowledge pools. Based on this research, the exposure of local firms to international standards and competition can lead to integration of local economies into global value chains and the overall growth of the region.

Building on the role of multi-locational firms in regional development, Kogler et al. (2023) further elucidate how the diversification of regional economies is deeply influenced by the dynamics within inventor and firm collaboration networks. The study suggests that regions with dense and diverse collaboration networks, where strong connections exist between various actors, are more successful in fostering the spread of knowledge within their area. This dynamic process of innovation enables the transfer and integration of knowledge across different technological domains, leading to the creation of new industries and sustaining economic growth.

Multi-locational firms also have implications for regional spillovers and the interaction of regional economies based on their spatial distribution. Studies have shown that the geographical proximity of firms, as reflected in the distribution of inventor locations and headquarters within a region, can influence the extent to which knowledge spillovers and

collaboration occur among firms within that region. As a result of this spatial agglomeration of firms, the region is able to create and strengthen innovation clusters as well as enhance the overall competitiveness of the region (Lychagin et al., 2016).

In order to find the right location for a multi-locational company, a variety of factors must be considered. These factors include cluster density within each region, capability, and ethnicity between regions, all of which have a tremendous impact on the location decision. As a result, these firms strategically chose to locate across multiple clusters to capitalize on the advantages provided by both clustered and non-clustered locations, demonstrating the nuanced considerations that drive their spatial dispersion strategies across multiple clusters. Having a variety of multi-locational firms in a cluster contributes to the cross-fertilization of ideas, the exchange of knowledge, and the creation of synergies that contribute to the development of a regional economy (Dhandapani et al., 2015).

The role of multinational corporations (MNCs) in influencing the global landscape of innovation has also been highlighted in previous studies. According to a study conducted by Crescenzi et al. (2022), multinational companies can act as catalysts for innovation by drawing on their diverse resources, capabilities, and networks across different countries and regions to make a significant impact on the global innovation ecosystem. This study explores the impact of MNC-led innovation on local economies, industries, and societies, highlighting both opportunities and challenges. It examines how multinational corporations engage with local stakeholders, governments, and institutions to create value, build sustainable partnerships, and address societal needs through innovative methods. The paper also discusses how MNCs influence regulatory frameworks, industry standards, and technological paradigms, shaping global innovation landscapes (Crescenzi et al., 2022).

Through their knowledge sourcing processes, multi-locational firms play an important role in driving innovation and enhancing competitiveness by accessing external knowledge from multiple sources. Therefore, knowledge management practices should be aligned strategically with local environmental influences in the context of multi-locational corporations. In order to enhance overall firm performance, it is essential to develop a strategic plan for knowledge management that takes into consideration the

specific geographical context in which subsidiaries operate. Consequently, MNCs should adapt their knowledge management strategies to local conditions in order to maximize the success of their subsidiaries (Dabić & Kiessling, 2019).

Overall, this literature review underscores the complex and multifaceted dynamics that drive regional economic development, highlighting the pivotal roles of knowledge, innovation, and economic geography. It reveals how these interrelated elements interact to foster growth and competitiveness in modern regional economies. Knowledge transfer and innovation are central to this process, as they enable regions to adapt to changing technological landscapes and economic conditions. This dynamic is further influenced by economic geography in terms of how and where knowledge and innovations are generated and distributed. By exploring these interactions, the review provides a comprehensive understanding of how regional economies can utilize their unique geographic and institutional characteristics to enhance their innovative capabilities and economic performance.

Building on this understanding, the study of economic geography offers a robust framework for comprehending regional development. Geographic concentration of industries, as highlighted by the benefits of clusters and the externalities of agglomerations, illustrates how proximity and strategic networking can significantly enhance regional economic vitality. These models demonstrate that both local and external knowledge sourcing play crucial roles in fostering innovation and growth. By leveraging the advantages of geographic concentration, regions can amplify their innovative potential and strengthen their economic performance through enhanced collaboration and knowledge exchange.

Furthermore, the influence of multi-locational firms is pivotal in shaping regional development. The dynamics of foreign direct investment (FDI) from these firms, combined with their strategies for acquiring and applying knowledge, significantly impact regional competitiveness. By driving technological innovation and facilitating the transfer of knowledge across borders, multi-locational firms contribute to economic growth and regional integration. Their presence underscores the importance of understanding how

global knowledge flows and investment strategies can enhance local economies and foster a more interconnected regional landscape.

In conclusion, this review highlights the intricate and interdependent factors that drive regional economic development. It provides a nuanced understanding of the mechanisms involved, illustrating how knowledge dynamics, geographic concentration, and the activities of multi-locational firms collectively shape regional growth and competitiveness. As shown in this chapter, there is a rich body of literature examining the dynamics of innovation and knowledge transfer. This provides context for the research question of whether non-local firms introduce new ideas into regional economies. Studies, such as those by Asheim and Isaksen (2002) and Henderson et al. (2012), have shown how non-local firms and geographical clusters contribute to regional innovation systems.

Research Questions

The core research question guiding this study is whether multi-locational firms introduce different technologies into regional economies and how they influence local innovation systems. This inquiry arises from a broader understanding that regional economic transformation through innovation is shaped not only by localized factors but also by the influx of external knowledge and technologies. Multi-locational firms, operating across various regions, have access to diverse knowledge pools and innovation networks, which they may transfer to local economies. Consequently, this study seeks to explore whether these firms contribute novel technologies that differ from those generated by local firms, and how such external contributions impact the dynamics of regional innovation systems.

One of the key elements of this research is to examine the knowledge sourcing practices of multi-locational firms. These firms often engage in global knowledge sourcing, drawing on technological developments from other regions and transferring them to local markets. By analyzing patent data, this study aims to quantify the extent to which multi-locational firms bring new technological innovations into regional economies and assess how these differ from locally developed technologies. In addition, the research considers the influence of geographic concentration and regional innovation clusters. According to Porter's theory, such clusters are essential for fostering innovation, relying on both local specialization and external knowledge inflows. The presence of non-local firms within

these clusters poses the question of whether they contribute to regional specialization by introducing new technologies or if they dilute local strengths by pursuing broader, non-local strategies.

Furthermore, the role of multi-locational firms as agents of structural change is central to this research. These firms, due to their operations in multiple regions, have the potential to act as conduits for knowledge transfer, facilitating the flow of new technologies across regions and sectors. This can drive innovation in areas that may have otherwise stagnated. However, there is also the risk that their presence could lead to an over-reliance on external knowledge sources, potentially weakening the local knowledge base. To address these concerns, this study will map technological knowledge flows using patent data from key Canadian tech hubs, such as Toronto, Ottawa, Waterloo, Montreal, Calgary, and Vancouver, to understand the extent to which non-local firms introduce new technologies and how these technologies spread within regional innovation systems.

In light of this context, the research hypothesizes that non-local firms introduce distinctive technologies into regional economies, which can either drive local innovation or create dependency on external knowledge sources. The outcomes of this dynamic depend on the region's industry specialization, the nature of the firms' operations, and the degree of interaction between local and non-local firms. By quantifying the technological contributions of multi-locational firms and mapping innovation flows between local and non-local firms across different regions, this research seeks to provide new insights into the role of multi-locational firms in shaping regional innovation systems and long-term economic growth.

Building on these foundations, the current research aims to address a specific gap by examining how non-local firms influence regional technological landscapes across key Canadian tech hubs. This study extends the understanding of regional innovation ecosystems by focusing on the distinct contributions of multi-locational firms and their role in shaping local technological advancement. The following chapter will detail the methodology employed to analyze patent data from these hubs, offering insights into how these external knowledge sources impact regional innovation processes.

Chapter 3
Methodology

3.1 Research Design

In this chapter, I outline the type of research methodology that was used to gather and analyze the data in order to address the research question and in order to help us gain a deeper understanding of the situation with technologies in local innovation systems. As I seek to answer the research question by analyzing the number of new technologies that are emerging, I use a quantitative methodology to collect, analyze, and interpret numerical data in order to answer my study question.

3.1.1 Quantitative Research

A quantitative methodology is a research approach that involves the collection and analysis of numerical data to gain a deeper understanding of phenomena, relationships, or patterns through a systematic investigation. In this methodology, I use statistical techniques to draw conclusions and make inferences based on the data I have gathered. This methodology can be useful for this research as it allows researchers to systematically examine different aspects of a phenomenon, such as the effects of resources and capabilities on firm performance and the development of frameworks for analyzing competitive advantage (Ferreira & Fernandes, 2017; Hemmati et al., 2016).

Several studies have highlighted the importance of quantitative methods in assessing and promoting innovation in various contexts (Oduro et al., 2021). Quantitative methodology can also be regarded as systematic and data-driven approach that can help to understand and improve innovation processes. In fact, a number of studies indicate that empirical studies with quantitative data are preferred in order to explore innovation aspects in an effective manner. For example, Gomes and colleagues used a quantitative methodology to analyze the impact of Science and Technology Parks on regional development, emphasizing the importance of structured frameworks supported by quantitative variables when assessing innovation outcomes (Gomes et al., 2022). Also, according to Lopes et al. (2021) , quantitative methods were employed to identify the key factors influencing

regional innovation performance in the European Union, demonstrating the utility of quantitative analysis in identifying regional innovation dynamics in the EU. Additionally, Hintringer et al. (2021) conducted a quantitative analysis to examine the influence of innovation factors on economic growth in South Korea, emphasizing the importance of quantifiable innovation metrics in driving economic development.

These studies demonstrate that when examining factors contributing to innovation and regional development, as in this research, employing a quantitative methodology is an effective empirical approach as it provides a structured framework for identifying patterns and relationships. A quantitative analysis of patent data is crucial for this study in order to uncover detailed insights into how innovation is distributed across six selected tech hubs.

To conduct a quantitative analysis of patent data in a region and evaluate innovation within that region, a systematic approach can be adopted based on insights from reputable sources. There is no doubt that patent data provide a valuable resource for assessing innovation activities within a particular region or area. The innovation landscape of a region can be explored through the collection of patent documents related to the target technology and the application of quantitative data analysis methods. It is believed that patents serve as a record of innovation activity, with patent counts often serving as a proxy for innovation in a particular field (Jun, 2021; Stek, 2020). The quantitative analysis of patent data can play a crucial role in identifying innovation city-regions that are developing innovative technologies and further in analyzing the path their development is taking (Stek, 2019).

In the context of quantitative analysis of patent data and the evaluation of innovation within a region, R programming is an extremely useful tool. The effectiveness of R for patent analysis and innovation evaluation has been demonstrated in a number of studies. As an example, Choi et al. (2015) presented a predictive model of technology transfer using patent analysis, emphasizing the use of text mining for patent analysis in R. Using R, this paper illustrates how patent documents can be collected, term-document matrices can be constructed and patent data can be analyzed for the purpose of predicting technology transfer.

3.1.2 Quantitative Descriptive Research Design

Descriptive quantitative research aims to describe characteristics or phenomena in a systematic and accurate manner without manipulating variables. The goal of this method is to observe and measure things as they are in their natural state. The primary objective of this type of research design is to collect quantitative data in order to identify patterns, trends, and relationships within a population. Using tools such as surveys, observational methods, and secondary data analysis, this approach provides a comprehensive overview of the subject matter, providing important factual and statistical information that assists in understanding current conditions (Siedlecki, 2020).

The purpose of this research design is to understand the prevalence, distribution, relationships, and causes of variables without exploring their causes. For instance, when studying patents and innovation within Canadian technology hubs, a quantitative descriptive approach would involve collecting data regarding the number and types of patents filed, identifying the key technological classes prevalent in different cities, and analyzing trends over time.

Therefore, in this research, I will use a quantitative descriptive method to analyse the gathered secondary data and comprehensively discuss the contribution and trends of patents in the six selected tech hubs in Canada.

3.2 Study Target Selection

The target of study in this text is "multi-locational companies with at least one establishment in selected six tech hubs in Canada" .This concept refers to companies that operate from multiple locations in the six key tech hubs of Canada, namely Toronto, Montreal, Vancouver, Waterloo, Ottawa, and Calgary. For this study, ‘tech hubs’ refer to cities with high levels of innovation in Canada. Indeed, an extension of this study would be to refine to the scope of tech hubs by identifying more carefully the sectors and exact geographical areas that represent the hotbeds of innovation in Canada. Such an approach would, however, require data and analyses that fall outside of the scope of this thesis. Therefore, for this study, tech hubs equate large innovative cities in Canada.

These firms strategically select these specific technology hubs in order to take advantage of the unique advantages each location offers, such as access to talent, research institutions, funding opportunities, and an ecosystem that facilitates innovation and growth. Throughout the course of this research project, we shall examine companies with multiple locations within or outside of Canada that have at least a plant located in one of the selected six technology hubs.

To precisely define our geographic target, we will utilize the Census Metropolitan Area (CMA) as delineated by Statistics Canada. Statistics Canada defines a census metropolitan area (CMA) or a census agglomeration (CA) as one or more adjacent municipalities centered around a population center (known as the core). The population of a CMA must be at least 100,000 according to the current Census of Population Program, of which at least 50,000 must live in the core, based on the adjusted data from the previous Census of Population Program. A CMA must also have a core population of at least 10,000, according to data from the previous census. A municipality must be integrated with the core by commuting flows, derived from prior Census Program data on place of work, in order to be included in the CMA or CA (StatisticsCanada, 2021a).

Based on the Census Metropolitan Area (CMA) definition, our selected six agglomeration areas are Toronto, Montreal, Calgary, Vancouver, Ottawa-Gatineau, and Kitchener-Cambridge-Waterloo. For the two tech hubs of Ottawa and Waterloo, firms located in Gatineau, Kitchener, and Cambridge are included, as there is a single CMA code for Ottawa-Gatineau and one for Kitchener-Cambridge-Waterloo. Therefore, in this text, "Waterloo" refers to Kitchener-Cambridge-Waterloo, and "Ottawa" refers to Ottawa-Gatineau in terms of location.

The socio-economic, geographical, and cultural contexts of the selected six Canadian cities play a critical role in shaping their respective innovation ecosystems and technological landscapes. Each city is characterized by distinct industrial specializations, population dynamics, and cultural influences, all of which contribute to their unique positions within the national and global economy. To establish this context, the following provides an overview of each city:

Toronto

Toronto, Canada's largest city, is a significant economic hub characterized by a diverse economy that spans finance, technology, manufacturing, and cultural industries. According to the 2021 Census profile, Toronto had a population of 6,202,225, making it one of the most populous cities in North America (StatisticsCanada, 2021b). The city's economy is notable for its status as a global financial center, hosting numerous banks, insurance companies, and investment firms. In 2020, Toronto's nominal GDP was approximately CAD 430.9 billion, accounting for roughly 10% of Canada's total GDP(StatisticsCanada, 2023). In terms of employment, Toronto's labor force participation rate stands at around 64.4%, with significant job creation in sectors such as finance, technology, healthcare, and education (StatisticsCanada, 2021b). Geographically, Toronto is situated in Southern Ontario along the northwestern shore of Lake Ontario, facilitating transportation and trade and connecting the city to both national and international markets.

Toronto's cultural diversity and economic structure are closely interconnected, with each influencing the other. With 51% of its population being immigrants, the city benefits from a wide range of perspectives and skills, which contribute to the overall workforce and the exchange of knowledge across industries. This diversity is reflected in Toronto's economic activities, particularly in key sectors like finance, technology, healthcare, and education. The demand for specialized skills in these industries encourages the flow of talent and knowledge, both locally and internationally. Collaboration between various sectors and the integration of diverse cultural perspectives help drive innovation and adaptability in the city's economy, shaping Toronto's broader development.(StatisticsCanada, 2021b).

Montreal

Montreal, Canada's second-largest city, serves as a vital economic center with a diverse economy that includes sectors such as aerospace, information technology, pharmaceuticals, and cultural industries. According to the 2021 Census profile, Montreal had a population of 4,291,732 (StatisticsCanada, 2021b), making it one of the largest cities in North America. The city's economy is bolstered by its reputation as a hub for innovation, particularly in the aerospace and pharmaceutical sectors, which are key

contributors to both regional and national economic growth. In 2020, Montreal's nominal GDP was approximately CAD 228.7 billion, accounting for a significant portion of Quebec's economic output (StatisticsCanada, 2023). Montreal's labor force participation rate stands at 61.4%, with significant employment in industries like aerospace, healthcare, education, and IT (StatisticsCanada, 2021b). Geographically, Montreal is located in Southern Quebec on the Island of Montreal, strategically positioned along the Saint Lawrence River, which serves as a major corridor for transportation and trade. This location enhances the city's connectivity to international markets, particularly through its port, one of the busiest in Canada.

Montreal's cultural diversity and economic landscape are closely linked. The city is known for its bilingual population, with a substantial portion of residents speaking both French and English, facilitating international business and cross-cultural collaboration. Immigrants make up about 24% of Montreal's population, contributing a wide range of skills and knowledge to the workforce. This diversity is particularly evident in sectors like technology, healthcare, and creative industries, where the blending of different cultural perspectives encourages innovation and knowledge sharing. The city's economic development is shaped by this cultural mix, along with strong collaborations between industries and educational institutions, driving the transfer of knowledge and the continued evolution of Montreal's economy (StatisticsCanada, 2021b).

Ottawa

Ottawa, Canada's capital city, is a vital economic center with a diverse economy encompassing sectors such as public administration, technology, and healthcare. As of the 2021 Census, Ottawa had a population of 1,488,307 (StatisticsCanada, 2021b), making it one of the largest cities in the country. The city plays a crucial role as the political heart of Canada, hosting numerous federal government departments and agencies. In 2020, Ottawa's nominal GDP was approximately CAD 74.8 billion, contributing significantly to the national economy (StatisticsCanada, 2023). The labor force participation rate stands at around 64.1%, with notable employment growth in areas such as technology and healthcare, reflecting the city's evolving economic landscape.

Geographically situated in Eastern Ontario along the Ottawa River, the city benefits from its strategic location, enhancing transportation and trade connections to both national and international markets. Ottawa's demographic diversity also enriches its economy, with about 27% of residents identifying as immigrants, contributing a range of perspectives and skills. This cultural mix fosters innovation and collaboration within key sectors, particularly technology and the creative industries. The demand for specialized expertise encourages knowledge exchange between local businesses, educational institutions, and government bodies, promoting adaptability and resilience in the city's economic development (StatisticsCanada, 2021b).

Waterloo

Waterloo, located in Ontario, Canada, is noted for its contribution to the technology and innovation sectors. In 2021, the Waterloo Census Metropolitan Area (CMA) had a population of approximately 575,847 (StatisticsCanada, 2021b). The economy is primarily driven by the technology industry, encompassing numerous startups and established firms in software development and information technology. In 2020, Waterloo's nominal GDP was around CAD 32.9 billion, contributing significantly to the provincial economy (StatisticsCanada, 2023). The labor force participation rate is about 63.7%, with job growth particularly evident in technology and professional services.

Strategically situated within the Waterloo Region, the city provides access to major markets in Southern Ontario. The presence of educational institutions, particularly the University of Waterloo, supports a skilled workforce and promotes partnerships between academia and industry. This interaction fosters knowledge transfer and collaboration across sectors, contributing to the region's economic development and innovation.

Calgary

Calgary, located in Alberta, Canada, is an important economic center known for its sectors such as energy, technology, and finance. According to the 2021 Census, Calgary had a population of approximately 1,481,806 (StatisticsCanada, 2021b). The city plays a significant role in the oil and gas industry, contributing to its status as a major energy hub. In 2020, Calgary's nominal GDP at basic prices was approximately CAD 102.7 billion,

reflecting its considerable impact on the provincial economy (StatisticsCanada, 2023). The labor force participation rate is around 69.6%, with employment growth concentrated in energy, technology, and professional services.

Calgary's strategic position near the foothills of the Canadian Rockies enhances its role as a key trade and transportation hub. The presence of various educational institutions and research centers supports the development of a skilled workforce .This interaction fosters innovation and knowledge transfer across sectors, contributing to the city’s economic resilience and growth.

Vancouver

Vancouver, situated in British Columbia, Canada, serves as a prominent economic hub, marked by a varied economy that spans technology, film and television, tourism, and natural resources. With a population of around 2,642,825 as of 2021 (Statistics Canada, 2021b), Vancouver demonstrates significant economic activity, boasting a nominal GDP at basic prices of approximately CAD 163.8 billion in 2020 (Statistics Canada, 2023). The city's labor force participation rate is roughly 62.6%, with considerable employment growth primarily in the technology and service sectors.

The cultural diversity of Vancouver enriches its social fabric, as residents hail from various backgrounds, contributing unique traditions and perspectives. The city is home to prestigious educational institutions, such as the University of British Columbia, which plays a crucial role in fostering research and innovation, equipping the local workforce with essential skills. Moreover, Vancouver's strategic coastal location provides vital access to the Pacific Ocean and significant trade routes, enhancing its role as a key center for international trade and cultural interaction, further solidifying its dynamic community.

Technology hubs are metropolitan areas with high concentrations of technology companies, robust innovation activities, and supportive infrastructure. It is characterized by a high density of technology companies, a significant volume of patent filings, substantial venture capital investments, and the presence of renowned research universities and institutions (Atiase et al., 2020). In this study, I focus on the tech hubs that have been emerged in our six selected CMAs.

In assessing a technology hub within a specific region, one of the most common means of evaluating innovation and the development of technology is through the number of patent registrations. The patents serve as an indicator of the firm's input of innovative resources as well as a tool for measuring the impact of the innovation outcomes of a firm (Wang et al., 2020). Researchers can gain insights into the level of innovation and technological development in an ecosystem by analyzing the number of patents filed by companies within that ecosystem (Alstadsæter et al., 2018).

The use of information from patent classification schemes can shed light on the technological specialization of specific tech hubs. One of the most well-known classification is the Cooperative Patent Classification (CPC) system which has emerged as one of the most significant extensions of the International Patent Classification (IPC). CPS provides a framework for searching patent applications internationally in a wide variety of technological areas. The Cooperative Patent Classifications (CPC) is developed collaboratively by the European Patent Office (EPO) and the United States Patent and Trademark Office (USPTO). Patents can be mapped through CPC to conduct portfolio analysis and compare strengths and weaknesses. The CPC term structure is organized hierarchically into sections, classes, subclasses, and groups for each term. Each term consists of a code that includes a combination of letters and numbers representing these categories. In this context, the first digit of a classification code refers to the section, which represents a broad area of technology. The subsequent digits define classes, subclasses, and groups within these sections, providing detailed information about inventions in a specific fields (Ma et al., 2023) (Leydesdorff et al., 2017).

The analysis of patent classification codes can be used to demonstrate the level of technological specialization of a particular region within the context of a technology hub. The distribution of patent classification codes within a particular tech hub can help us with information regarding the dominant technology domains and areas of expertise within the hub (Risch & Krestel, 2019).

When discussing tech hubs, it is important to consider the concept of hub location under competition, in which firms strategically select the location of their hubs in order to attract customers and enhance the quality of the services they provide while minimizing their

costs. As a result of this competitive environment, companies in the technology sector need to assess and quantify the technological advantages offered by each of their hubs. The understanding of these advantages can help companies optimize their operations and innovation strategies across different locations, ultimately enhancing their competitiveness and growth. (Huang et al., 2019). Accordingly, examining the principle of comparative advantage can provide valuable insight into how companies can further refine their strategies in order to maximize the benefits of their multi-locational operations.

Comparative advantage, a fundamental concept in economics introduced by David Ricardo in 1817, refers to a geographical location's ability to produce goods at a lower opportunity cost than other regions. This implies that even if one location is less efficient in producing all goods compared to another, it can still benefit by specializing in goods where it has a relative efficiency advantage and trading for others. By doing so, locations can achieve higher overall productivity and mutual benefits from trade (Costinot, 2009).

In order to calculate a location's comparative advantage when it comes to technology, RTA can be a useful index to utilize. The Revealed Technological Advantage (RTA) index is a significant tool for assessing the technological advantages of different location in various fields. In order to calculate the RTA Index, the number of patents acquired within a specific location, including country, city, etc., in a particular technology sector is divided by the total number of patents acquired by that specific location across all technology sectors. In today's global economy, this index is a valuable tool for evaluating a location's technological competitiveness and comparative advantage. This index can be calculated to identify the areas of technological specialization in cities of a country as follows:

$$RTA_{ij} = \frac{\frac{P_{ij}}{P_i}}{\frac{P_{ic}}{P_c}}$$

Where:

- P_{ij} is the number of patents related to the technology sector j in the region i.
- P_i is the total number of patents in region i.

- P_{ic} is the total number of patents in all technologies for region i..
- P_c is the total number of patents in all technologies in the target country.

When $RTA_{ij} > 1$, region i has a comparative advantage in technology field j (Laursen, 2015).

In this research, we are going to use RTA to identify the areas of technological specialization in our selected tech hubs.

As mentioned before, patent data is regarded as a rich source of information for new technologies, and analyzing innovation. We will use the following datasets to obtain the required patent data regarding our selected tech hubs in Canada:

3.3 Data collection

Using the ORBIS dataset, one can gain comprehensive insight into a firm's financial and productive activities around the world. The dataset covers more than 500 million companies worldwide in 2024, offering detailed insights into their ownership structures on a domestic and international scale. For this reason, it is a valuable tool for analyzing patent-related information. In order to analyze the innovation activities and patent portfolios of firms in more depth, researchers can utilize the ORBIS dataset, which provides researchers with nationally representative firm-level data (Kalemli-Özcan et al., 2015).

As part of various studies, the ORBIS dataset has been utilized to merge patent applications with firm-level data, thereby facilitating detailed analyses of the technological landscapes and the innovation strategies of firms (Montobbio et al., 2022). In addition, the ORBIS dataset has been used in studies focused on patent classification, patent mapping, and technology transfer analysis. Researchers have used the dataset to geocode worldwide patent data, enabling detailed geographic examinations of patenting activities (Rassenfosse et al., 2019).

In this study, I will use the largest cross-country firm-level database, ORBIS, to gather information regarding the location of the firms' establishments. This database combines information regarding location, industry, and ownership for both private and public firms.

Combining the ORBIS dataset with the United States Patent and Trademark Office (USPTO) data can offer a robust approach to analyzing innovation activities, patent portfolios, and technological landscapes. The ORBIS dataset provides comprehensive information on firms' financial and productive activities globally, while the USPTO database offers detailed patent information, making the integration of these datasets valuable for research purposes.

The US patent application process is known to be time and cost-efficient which has encouraged firms from countries like Canada to use this system (Nagaoka et al., 2010). The initial data was extracted from the USPTO by accessing the USPTO Bulk Data Storage System[1] and contains the following information: the name of the assignee organization, the names and locations of the inventors, the year of application, and details on the technological classification(s) individual patents fall into. All this information will be used for the analysis in this paper. USPTO data was then merged with the geographical and ownership information from Orbis, based on the names of the assignee organization. Patent records are geolocated based on the matched location of the residence(s) of the inventor(s) and the establishments of the firm in Canada, for which addresses I extracted from Orbis.

For this project, I extracted data on branches and subsidiaries in two separate steps. Initially, I imported a list of firms from the USPTO database into the Orbis platform in order to gather comprehensive information regarding the branches of firms associated with the patent data. As a result of this process, I was able to analyze the location and capabilities of each firm's establishments. Initially, I imported a list of 500 firms, which is the maximum number possible per import. To pinpoint relevant establishments within this geographical region, I selected "Canada" as the world region through Orbis's search functionality. In order to cover all necessary firms, I repeated this process multiple times.

[1] https://www.uspto.gov/learning-and-resources/bulk-data-products

Following the display of the results, I customized the data view by selecting specific columns. This included information such as the name of the company and contact information, as well as address details, including postcode, city, longitude, latitude, and the region within the country. The legal status of each firm was also included to gain an understanding of its operational standing. To determine ownership information, I reviewed the shareholder information, focusing on the Global Ultimate Owner and Domestic Owners and extracting their names, cities, and ownership percentages. When exporting the results, I managed large datasets by exporting them in chunks, facilitating easier data handling and analysis.

The second step involved extracting data related to subsidiaries. Similar to the previous section, I imported up to 500 firms per batch allowed from the USPTO database into Orbis. Our strategy was adjusted to target ownership information, specifically replacing affiliates with subsidiaries, by using the search functionality. I included criteria for subsidiaries to be ultimately owned globally or domestically, with ownership percentages ranging from 50% to 100%, and added branch information focusing on Canadian establishments. Data view was customized to include the name of the company, contact information (address line 1, postcode, city, longitude, latitude, and region), and legal status. As for ownership, I focused on the Global Ultimate Owner and the Domestic Owner, extracting their names, cities, and ownership percentages. By doing so, comprehensive subsidiary information was captured.

By analyzing patent data from firms located in the six major Canadian tech hubs, our research aims to gain comprehensive insights into the impact of knowledge sourcing on innovation growth within these firms. Knowledge sourcing, which involves the acquisition of external knowledge from diverse geographical locations, is hypothesized to play a crucial role in fostering innovation. The central research question guiding this study is: Do nonlocal firms introduce different technologies into local innovation systems?

In total, the following table shows the total population that will be studied in our six selected tech hubs of Toronto, Montreal, Vancouver, Waterloo, Ottawa, and Calgary during the period of 2000-2019.

Table 1. Target Population

Variable	Count
Unique firms	11880
Unique patents	82849
Unique CPC subclass	629

3.4 Data Processing

R programming is one of the most widely used statistical computing and graphics tools. As an open-source language and environment, it provides a variety of statistical and graphical techniques, making it useful for data analysis in a wide range of fields. Due to its flexibility and extensive package selection, R is used extensively for statistical analysis, data visualization, and the development of statistical models. As a computing standard for analyzing data, it is an important tool for researchers, analysts, and practitioners across a variety of fields (Auker & Barthelmess, 2020; Braun & Murdoch, 2016).

In the first step, I need to integrate the disparate patent datasets into a unified and cohesive database. In order to accomplish this, R's data manipulation package, “dplyr”, was used, which facilitates the merging and restructuring of data frames. Once the data has been combined, the data should be cleaned. This process involves identifying and correcting inconsistencies, dealing with missing values, and ensuring that the data is accurate and reliable. To maintain the integrity of the dataset and to ensure that subsequent analyses yield valid results, a thorough cleaning process is essential. Following data cleaning, the processing phase will involve transforming the data into a suitable format for analysis.

As a next step, the data is grouped to identify patterns and trends within different segments based on the initial data processing. Using R, I will use the dplyr package to group the data by various dimensions such as firm location, technology type, and origin of knowledge inputs. By grouping the data in this manner, it is possible to analyze the innovation activities within and across tech hubs at a more granular level.

As we aim to study the dynamics of patents in the six selected tech hub locations and identify the classes of patents that shape the expertise of our selected locations, I will calculate a variable called Weight which can be used to calculate class shares at the city level which is defined as follows (Jaffe et al., 1993) :

$$Weight = CMA\ share \times CPC\ share$$

In this equation, Census Metropolitan Area (CMA) share, represent the part of the patent which is assigned to a specific geographic location. I other word, this share, determines how much of the patent's innovation activity can be attributed to that particular area. Using it, we can understand the contribution of each CMA to the overall innovation landscape. In the case of patents developed in collaboration by researchers in multiple CMAs, fractional shares may be assigned to each CMA based on the level of contribution from each location. For example, if a patent has 50% of its innovation activity in Toronto and 50% in Vancouver, Toronto's and Vancouver's CMA shares would be 0.5.

The second part in the above equation is Cooperative Patent Classification (CPC) share. This variable describes the portion of a patent that falls under a specific CPC subclass. Previously, I described the CPC system as a detailed and hierarchical classification system for patents. Based on the share, we can determine how much of the patent is associated with a particular CPC subclass, which reflects the technology focused on by the patent. As an example, if a patent covers multiple technological areas, it may be assigned fractional shares for each relevant CPC subclass. The CPC shares for a patent that is 70% related to subclass A and 30% related to subclass B would be 0.7 for subclass A and 0.3 for subclass B.

This weight is calculated by multiplying the CMA share by the CPC share, which gives an indication of how significant the patent is within a particular technology area. Using this weight, we can analyze the distribution and impact of technological innovations across different geographical and technical areas (Jaffe et al., 1993).

Using R to group and analyze our patent data based on different categories including location, CPC class and the weight of each class in each location, we will be able to

conduct a detailed and comprehensive investigation into the impact of knowledge sourcing on innovation growth.

In summary, the methodology chapter has established a structured and rigorous approach to investigating the influence of multi-locational firms on the innovation landscape within key Canadian tech hubs. Using a quantitative methodology to analyze patent data, this study aims to uncover key patterns in technological knowledge flows and evaluate nonlocal firms' impact on local innovation systems. In the next chapter, a comprehensive analysis of the patent data will be presented, offering in-depth insights into the innovation dynamics of each tech hub and providing empirical evidence to address the study's core research question.

Chapter 4
Results

In this chapter, when looking at the results of the study, we can visualize the extent of innovation happening in Canadian tech hubs by looking at the total number of patents in each city and how this number has evolved over time. This approach provides a clear picture of the innovative capacity within these regions. In addition, I calculated the Revealed Technological Advantage (RTA) of the ten most important patent classes in order to analyze the specialization of these technology hubs. By applying this method, one can gain an understanding of the unique technological strengths that define each city, as well as identify areas in which each of them is competitive.

Following the examination of innovation and specialization, this chapter also delves into the role of multi-locational firms within these tech hubs. I assess the significance of the most prominent multi-locational firms in each city by analyzing their share of patents. This analysis reveals how the presence and impact of multi-locational firms vary across different tech hubs. Furthermore, for the key specializations identified in each tech hub, I calculated the share of multi-locational firms within the class count shares. This provides a deeper understanding of how these firms contribute to and influence the specialized technological advancements in each region. By examining both the overall innovation and the specific contributions of multi-locational firms, we gain comprehensive insights into the dynamics shaping Canada's tech landscape.

4.1 Level of innovative and specialization in the six selected Canadian tech hubs

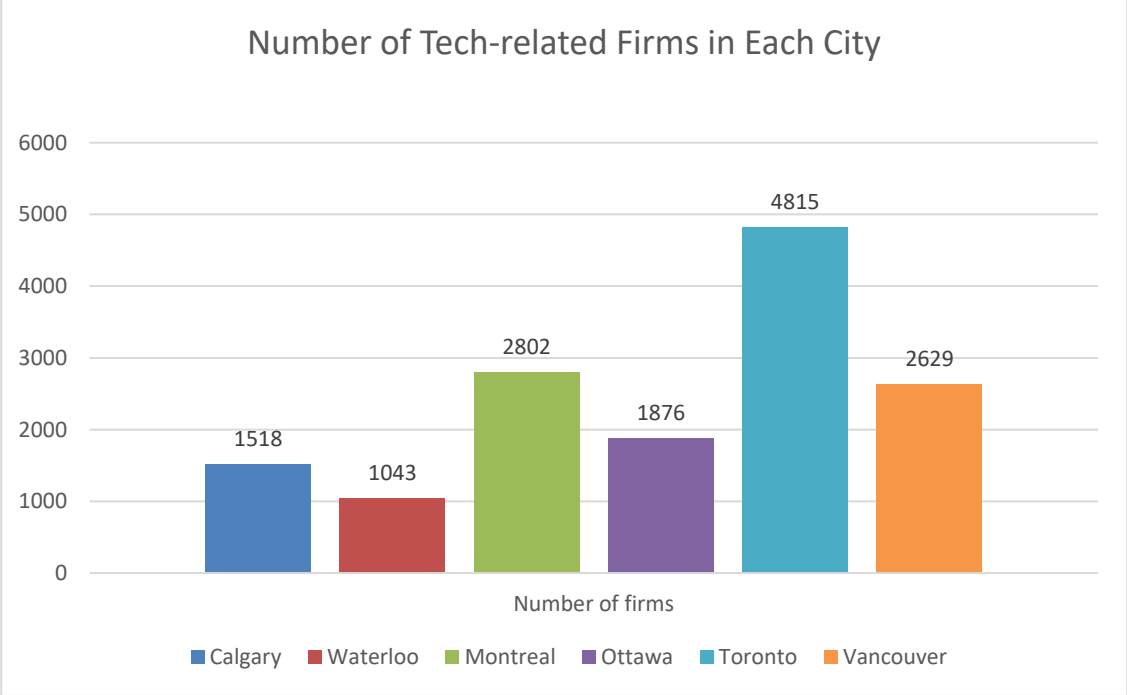
4.1.1 Innovation Capacity in the six selected Canadian tech hubs

In a tech hub, the number of tech-related firms is a significant indicator of the hub's vibrancy, innovation potential, and economic impact. An increase in the number of firms within a tech hub contributes to a more dynamic and competitive environment, which fosters greater knowledge creation, open innovation, and overall innovation performance. As more firms enter the hub, they bring diverse expertise, technologies, and perspectives, leading to richer interactions and collaborations among companies. This density of firms

facilitates the exchange of ideas, knowledge spillovers, and the formation of partnerships, which are crucial for innovation. Additionally, the competitive pressure among firms drives them to continuously innovate to maintain a competitive edge. The combined effect of these interactions and competition enhances the overall innovation ecosystem, leading to increased knowledge creation and improved innovation performance. It was also discussed that the innovation efficiency of high-tech small and medium-sized enterprises (SMEs) is positively correlated with the number of firms involved in the area. As more firms, particularly SMEs, populate the tech hub, they benefit from the increased availability of shared resources, talent, and infrastructure as mentioned (L. Liu et al., 2020).

In my research, the number of tech-related firms in the six selected tech hubs can be seen in the following graph:

Figure 1. Number of Tech-related Firms in Each City



I refer to "tech-related firms" by referring exclusively to patent assignees, which is an organization that has applied for a patent in order to be protected. Assignees of patents within a tech hub are an important indicator of the region's innovation potential and its ability to develop and nurture cutting-edge technologies.

The above graph illustrates the distribution of tech-related firms across six major Canadian tech hubs. Toronto leads significantly with 4815 firms, highlighting its role as a dominant tech center in Canada. In part, this concentration of firms can be attributed to to its infrastructure, large labor pool, and business environment, as well as its population size. The city, being the largest in Canada, serves as a key business and financial hub, attracting a variety of industries and multinational corporations. This status, overtaking Montreal since the 1960s, is deeply rooted in several historical and geographical factors. According to Artibise (1988), the city's strategic location and proximity to the United States played a significant role in fostering closer economic ties and facilitating trade, which contributed to Toronto's growing prominence. Additionally, the westward migration of economic activities within Canada further bolstered Toronto's position as the economic powerhouse of the nation. This shift, coupled with Toronto's strong infrastructure and diverse talent pool, enabled the city to evolve into the central hub of finance and business in Canada.

Montreal follows at the second place with 2,802 companies, reflecting a robust and active technology sector. This significant number of firms highlights Montreal’s strong innovation ecosystem. In fact, Montreal experienced a period of economic decline in the latter half of the 20th century, particularly as Toronto rose to prominence as Canada's financial center. However, the city managed to revitalize itself by leveraging its robust networks of universities, research institutions, and cultural assets. As noted by Turkina and Oreshkin (2022) , the city evolved its industrial districts and adapted its innovation patterns to foster economic growth.

Vancouver ranks third in Canada in terms of the number of tech-related firms with 2629 organizations, highlighting its emergence as a significant innovation hub. Vancouver's tech industry has grown in part due to its geographical proximity to U.S. West Coast markets like Seattle and Silicon Valley, which fosters cross-border exchanges of talent, capital, and innovation. Vancouver benefits from close cross-border interactions, which facilitate the flow of talent, capital, and innovation between Canada and the United States.

The city of Ottawa ranks fourth in Canada with 1876 firms, a position bolstered by several unique advantages. As the capital of Canada, Ottawa benefits from its connection to the

federal government, which provides opportunities for collaboration between public agencies and the private tech sector. . This close relationship with government entities provides local tech firms with opportunities to collaborate on projects that often receive significant funding and support.

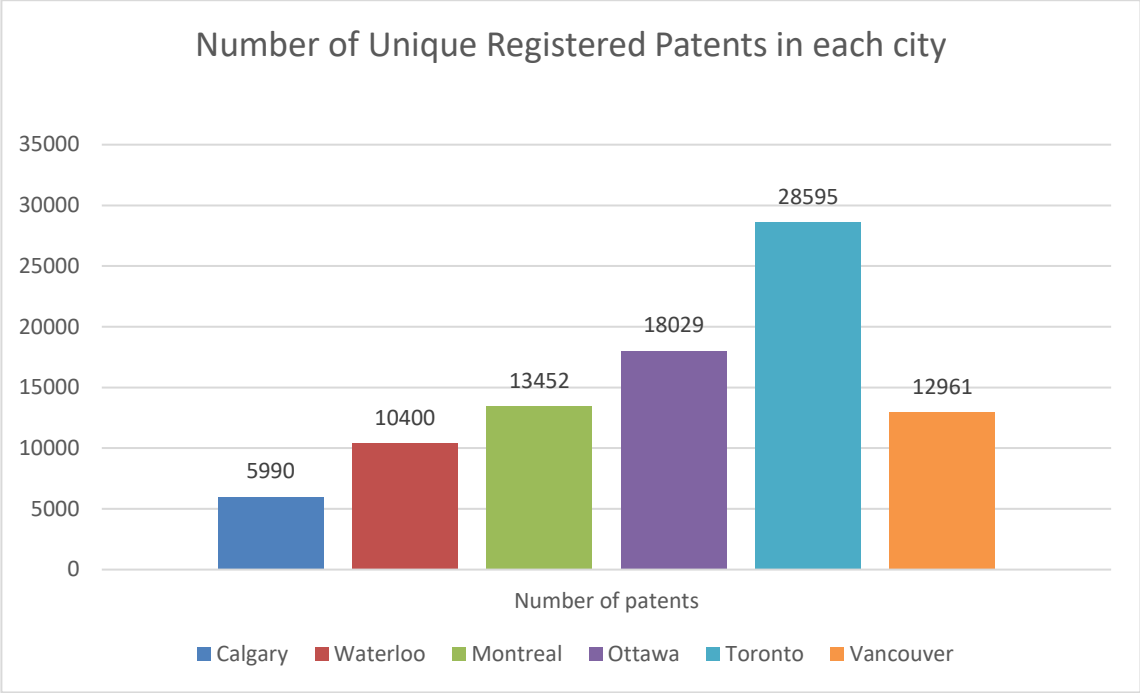
Calgary, ranked fifth in Canada with 1,518 tech firms, showcases a dynamic and evolving technology landscape. While historically recognized for its dominance in the energy sector, Calgary has begun to diversify its technological footprint. While there are emerging contributions in other fields, the enduring impact of energy-related industries is evident in the city's technological advancements and patent activity.

Waterloo has its roots deeply embedded in the success of Research In Motion (RIM), famously known for its Blackberry smartphones, and the presence of its prestigious university (Bramwell et al., 2008). Despite its relatively small size, Waterloo has established a significant technological footprint, boasting 1,043 organizations according to the figure 1. This impressive concentration of firms highlights the city's role as a vibrant hub of research and development of tech industry.

According to a sole evaluation of the number of firms operating in the technology sector, we can highlight that innovation capacities differ significantly among Canadian cities, with these variations closely aligning with the size and scale of their regional economies. Larger cities, such as Toronto, exhibit more extensive technological activities due to their broader economic base and infrastructure, supporting a more vibrant and competitive innovation environment. In contrast, smaller cities tend to have a smaller innovation capacity yet they still contribute valuable innovations

After assessing the number of firms in each tech hub, it is imperative to analyze the number of registered patents within these cities. Performing this analysis will enable us to determine the extent to which these firms are converting knowledge into proprietary technologies. The following graph shows the total number of patents that were registered in each teach hub from 2000 to 2019:

Figure 2. Number of Unique Registered Patents in Each City



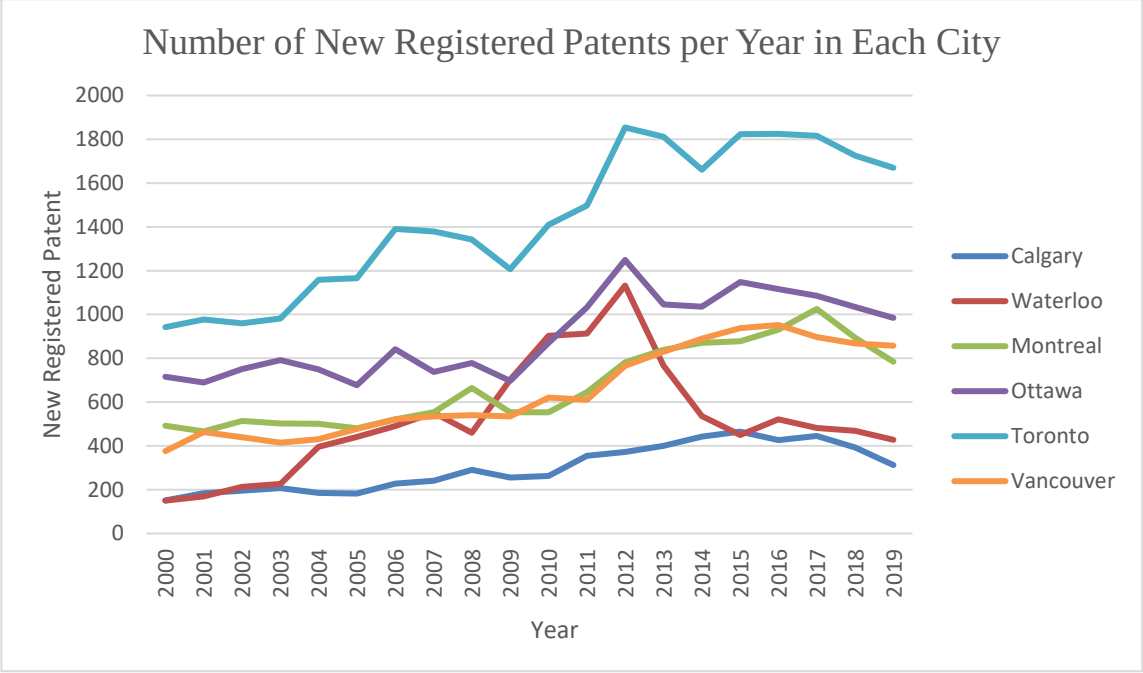
The data indicates that Toronto leads with the highest number of patents, registering a total of 28,595. This places Toronto at the forefront both in terms of the number of tech companies and patent applications, underscoring its prominence as a major technology center. Following Toronto, Ottawa exhibits a notable patent-to-firm ratio, with 1,876 firms producing 18,029 patents. This indicates a strong focus on technological advancement within a relatively smaller business community, as Ottawa ranks fourth among the selected six hubs in terms of the number of firms. Although Montreal is ranked second in terms of the number of firms, its patent count is third, with 13,452 patents. This lower patent-to-firm ratio compared to Ottawa suggests that firms in Ottawa have been more innovative than those in Montreal.

Vancouver, with 2,629 firms and 12,961 patents, closely mirrors Montreal's pattern, indicating a robust tech industry supported by a similar number of firms. Waterloo stands out with 1,043 firms generating 10,400 patents, highlighting its reputation for high innovation efficiency, likely driven by strong industry-academic collaborations. Calgary, with 1,518 firms and 5,990 patents, shows a developing but promising innovation landscape, suggesting potential for growth in its tech sector.

These comparisons demonstrate the degree to which innovation can vary across Canadian tech hubs, illustrating the fact that Toronto and Ottawa lead the way, while other Canadian cities, such as Waterloo and Calgary, are rapidly emerging in the space as significant players.

To examine the trends and patterns in patent filings and gain insights into the growth and development of each hub, The following graph can be used to analyze the performance of the six technology hubs during the studied period of 20 years:

Figure 3. Number of New Patents Per Year in Each City



The line graph depicting the number of new patents issued annually from 2000 to 2019 for Toronto reveals significant trends and fluctuations over the two decades. Starting at 942 patents in the year 2000, Toronto's innovation activity exhibited a steady increase, culminating in a peak of 1,811 patents in 2013. This highest point in 2013 indicates a period of robust innovation and technological development, possibly driven by favorable economic conditions, increased investment in research and development, and the growth of the tech industry in the city. Following this peak, the number of new patents experienced a slight decline but remained relatively high, settling at 1,670 patents by 2019. This trend suggests that although Toronto experienced some fluctuations after 2013,

it consistently produced a high number of patents, reflecting its continued importance in technological innovation.The line graph for Ottawa begins with 715 patents in the year 2000, reflecting a solid base of innovation. This number steadily climbs, reaching a peak of 1,249 patents in 2012. This peak suggests a period of intense technological advancement and innovation, likely influenced by strong research initiatives, government support, and a thriving tech sector. Ottawa's patent activity declined after 2012 but remained relatively stable, with 984 patents in 2019, indicating a steady innovation environment. In contrast, Waterloo starts with a more modest 150 patents in 2000 but experiences a remarkable increase, peaking at 1,132 patents in 2012. Waterloo's patent activity highlights its role as a growing tech center. However, post-2012, Waterloo sees a notable decline in patent activity, with the number of new patents dropping to 428 by 2019. This decline could be attributed to various factors, such as market saturation, shifts in industry focus, or changes in research funding and investment.

The graph for Montreal and Vancouver shows similar trends in innovation activity over the two decades. In Montreal, the number of patents started at 492 in the year 2000. This figure grew steadily, reaching a peak of 1,025 patents in 2017, indicating a significant surge in technological advancements and research outputs. However, after this peak, the number of new patents declined to 785 by 2019, suggesting a slight reduction in patenting activity but still maintaining a relatively high level of innovation. Vancouver also displayed a similar trend. Starting with 376 patents in the year 2000, Vancouver experienced a consistent increase in patenting activity, reaching its peak of 952 patents in 2016. This peak highlights a period of heightened innovation, similar to Montreal's peak in 2017. Following this, Vancouver saw a slight decline in new patents, ending at 858 patents by 2019, which, like Montreal, indicates a sustained yet slightly reduced level of innovation.

Despite the overall lower numbers, Calgary's patenting trends exhibit relatively minimal fluctuations over the two decades, suggesting a steady and consistent approach to innovation and technological advancements. Starting with 151 patents in the year 2000, Calgary's innovation activity showed a gradual increase over the years, reaching its

highest point in 2015 with 465 patents. However, following this peak, the number of new patents slightly declined, settling at 312 patents by 2019.

4.1.2 Specialization in the six selected Canadian tech hubs

In the next stage, to assess the specialization of the six leading Canadian tech hubs, I examine the CPC subclass with the highest concentration rate in each city, utilizing the Weight metric to determine if a city holds a comparative advantage in that subclass. By multiplying Census Metropolitan Area (CMA) share as representative of the portion of the patent that is allocated to a specific location and Cooperative Patent Classification (CPC) share as representative of the portion of a patent that is covered by a specific CPC subclass, the weight is calculated. As mentioned in the methodology chapter, weighted CPC class counts can be used as a measure of concentration of a specific subclass of CPC within a given city. When I calculated this variable for all the subclasses in all the cities, I arranged the list of the CPC subclasses based on the calculated weight.

The following table represent ten CPC subclass with highest patent counts in one city:

Table 2. Top 10 CPC Subclasses with Highest Counts in One City

City	CPC Subclass	Subclass total weighted count	Share of the class in city patent	RTA
Ottawa	H04L	2600	0.22	2.86
Toronto	G06F	2594	0.15	1.69
Ottawa	G06F	1304	0.11	1.25
Waterloo	G06F	1273	0.19	2.13
Ottawa	H04W	1240	0.10	2.93
Toronto	H04L	1076	0.06	0.80
Calgary	E21B	954	0.22	10.57
Waterloo	H04L	920	0.14	1.75
Vancouver	G06F	856	0.11	1.23
Vancouver	H04L	699	0.09	1.15

The H04L CPC subclass which refers to telecommunications and electric communication technologies was the subclass with the highest count of patent. It can be observed from

the data presented under "Share of the Class in City Patents" that the total number of patents in the H04L class in Ottawa represents approximately 22% of the total number of patents in the city. It is evident from this that Ottawa is considered one of the leading cities for telecommunications expertise.

As I mentioned earlier in the text, comparative advantage is one of the key factors that firms consider when they want to choose a location to operate. To calculate the comparative advantage I used RTA index. IF RTA>1, we can state that the city has a comparative advantage in that industry. As the table shows, the RAT of H04L in Ottawa is 2.86 which states the absolute comparative advantage of Ottawa in the telecommunication industry. According to this report, we are able to say that Ottawa is one of Canada's leading innovation hub in the field of telecommunications.

The second class with highest amount of weight of patent in a city is G06F in Toronto. G06F refers to electric digital data processing and represents almost 15% of all the patents registered in Toronto. This suggests that Toronto is an important center for digital data processing. Considering the RTA amount for this class in Toronto, the competitive advantage of Toronto in digital data industry can be assumed.

Moving to the third place, we have the same subclass of G06F but this time for Ottawa. Based on the analysis I conducted, the digital data processing sector forms nearly 11% of all patents filed in Ottawa during the 20 studies years. With RTA greater than one, we are also able to state that the digital data processing industry in Ottawa has a comparative advantage. However, this is not as strong as Toronto, because first and foremost, the subclass total weight is almost half that of Toronto. Secondly, the RTA is smaller than Toronto, demonstrating less concentration of industry players in the city and less comparative advantage.

The surprise arises when we observe that the fourth position in patent activity is also occupied by the digital data processing subclass G06F, this time in Waterloo. In Waterloo, G06F patents constitute about 19% of the total patents, with the city's Revealed Technological Advantage (RTA) being nearly double that of Toronto and Ottawa. This indicates that Waterloo has an absolute comparative advantage in digital data processing. The significant presence of G06F patents in Waterloo, combined with the strong

specialization in this subclass in Toronto and Ottawa, underscores Ontario's prominence in the field of digital data processing. This clustering of expertise within Ontario suggests a regional concentration of innovation, making the area a critical hub for advancements in computing and data processing technologies. The high level of patent activity in this subclass across these three tech hubs highlights Ontario's strategic importance in the digital technology sector.

In the fifth and sixth positions, the subclasses H04W (wireless communication networks) and H04L (transmission of digital information) were listed with the highest weights in Ottawa and Toronto, respectively. H04W accounts for 10% of the total patents in Ottawa, while H04L represents 6% of the total patents in Toronto. A significant disparity is evident in the RTA values: H04W in Ottawa has an RTA of 2.9, indicating a strong comparative advantage in the wireless communication networks industry. In contrast, H04L in Toronto has an RTA of only 0.8, indicating that Toronto does not have a comparative advantage in the transmission of digital information, as its RTA is below 1.

Calgary appears on the list of top 10 subclasses with the highest concentration of patents only once at the seventh position, through E21B subclass, which relates to earth or rock drilling and mining. This subclass represents approximately 22% of all patents filed in Calgary between 2000 and 2019. Notably, the Revealed Technological Advantage (RTA) for this subclass is reported as 10.58, the highest RTA value observed. This exceptional RTA demonstrates Calgary's absolute comparative advantage in the field of earth and rock drilling and mining, indicating that the city is a leading hub for innovation and technological development related to drilling machinery, such as rigs and platforms, as well as tools and techniques for drilling operations, including specialized drill bits and methods for managing drilling fluids.

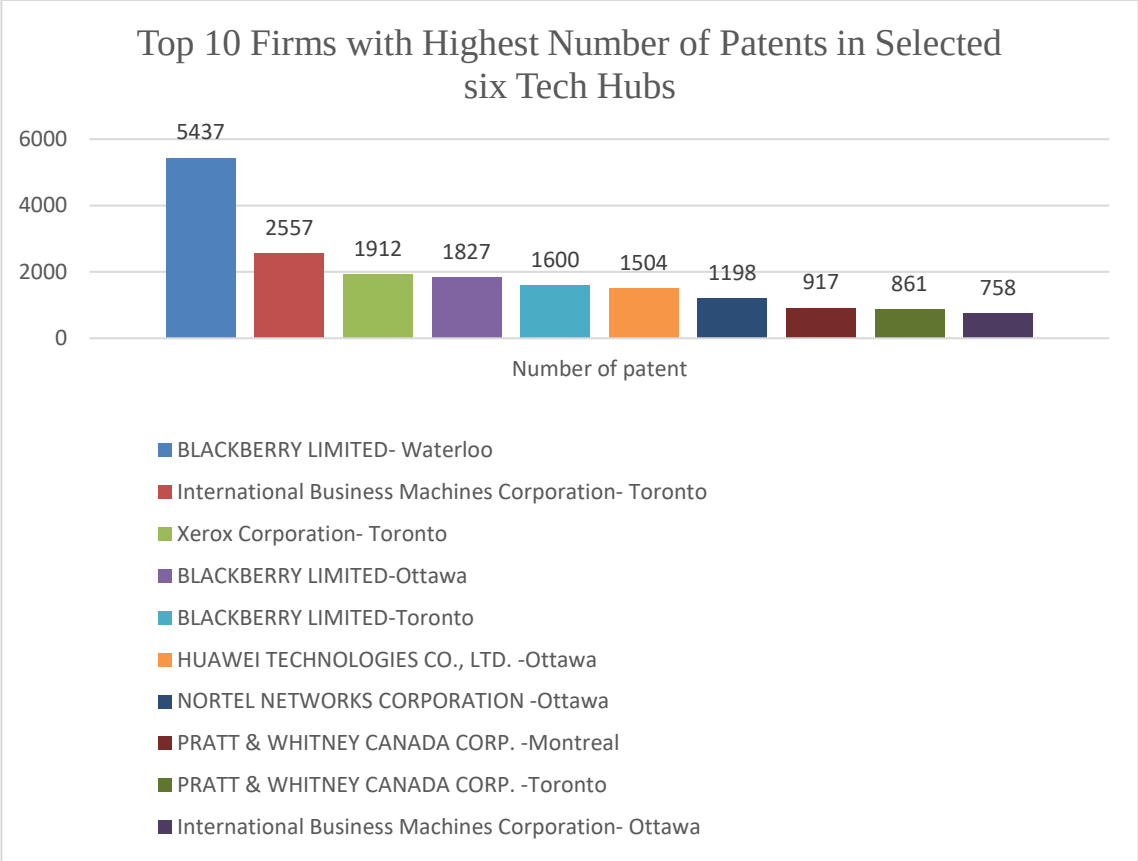
Transmission of Digital Information (CPC subclass H04L) in Waterloo is the 8th most concentrated subclass among all the classes, accounting for almost 14% of the city's total patents. Although this subclass is also concentrated in Toronto, there is a notable difference in the Revealed Patent Advantage (RPA). In Toronto, H04L does not show a comparative advantage, whereas in Waterloo, the RPA is 1.75, indicating a strong comparative advantage. Given that the weight of the patents in this subclass is not

significantly different between the two cities, Waterloo's comparative advantage may make it more attractive to new firms.

At the end of the list, two subclasses, G06F and H04L, are located in Vancouver. The G06F subclass covers technologies related to the processing of digital data through electronic means, such as general-purpose digital computers, data processing systems and hardware components. This subclass accounts for nearly 11% of the total patents in Vancouver. Following, the last subclass, H04L, pertains to the transmission of digital information using various communication systems and techniques such as data transmission networks, communication protocols and security techniques. H04L represents 9% of the total patents in Vancouver. Both subclasses, G06F and H04L have RTA greater than 1, indicating that Vancouver has a comparative advantage in these fields which can be mean that the city has a higher specialization and productivity in digital data processing and digital information transmission.

Before transitioning to the firm-based results, we first identified the top ten firms with the highest number of patents across the six selected tech hubs. This preliminary analysis was conducted to provide an overview of the leading players in the field of innovation within these hubs. The detailed results can be find in the following:

Figure 4. Top 10 Firms with Highest Number of Patents in Selected 6 Tech Hubs



The given graph illustrates the top ten firms with their highest number of patents in our selected tech hubs. BlackBerry Limited stands out with a substantial presence in Waterloo, holding 5437 patents, and also maintains a notable footprint in Ottawa and Toronto with 1827 and 1600 patents respectively. BlackBerry Limited, headquartered in Waterloo, is known for its pioneering smartphones, but the company has evolved into a provider of enterprise software and services, including cybersecurity solutions, endpoint management, and embedded systems (Middleton et al., 2021). Given that the digital data processing subclass is highly concentrated in Ottawa, Toronto, and Waterloo based on the Table 2, it's likely that the company has leveraged this infrastructure to enhance its operations. Waterloo, in particular, has nearly doubled the RTA rate compared to the Toronto and Ottawa in this regard, indicating a higher comparative advantage. This strong advantage likely influenced the decision to establish Waterloo as the company's headquarters.

International Business Machines Corporation (IBM) follows with 2557 patents in Toronto and 758 in Ottawa. A global leader in technology and consulting, IBM maintains an extensive patent portfolio that illustrates its dedication to innovation and technological advancement within the Canadian market. The company offers a wide range of services, including cloud computing, artificial intelligence, data analytics, and cybersecurity (Hill et al., 2006).

Xerox Corporation, also in Toronto, has secured 1912 patents, placing in the third place among the firms with the highest number of patents in the six studies tech hubs. The Xerox Corporation is a leader in the document management industry. It operates in the technology and business services sector. A variety of products and services are offered by Xerox, such as printers, copiers, digital document solutions, and IT services to support business productivity and digital transformation (Kikawada & Holtshouse, 2001) .

Huawei Technologies, with 1504 patents and Nortel Network cooperation with 1198 patent, both concentrated in Ottawa, emphasize the region's importance as a telecommunications hub. On the Canadian market, Huawei is a leader in the telecommunications sector, focusing on providing network equipment, telecommunications solutions, as well as consumer electronics such as smartphones (Zaamout et al., 2019). Historically, Nortel Networks Corporation was a major player in the telecommunications industry. In spite of declaring bankruptcy in 2009, Nortel was once a leading provider of networking solutions and telecommunications infrastructure. Its technology and patents have been acquired by a variety of companies over the years (Massey et al., 2002).

Pratt & Whitney shows a diversified presence, contributing 917 in Montréal and 861 patents in Toronto reflecting its influence in aerospace technology. The Pratt & Whitney Canada Corporation (P&WC) is a prominent Canadian aerospace manufacturer. This company is a subsidiary of the American company Pratt & Whitney, which is itself a division of Raytheon Technologies. As a company with its headquarters in Longueuil, Quebec, P&WC designs, manufactures, and service aircraft engines for a variety of aviation applications (Salam et al., 2008) .

Overall, this data shows how the distribution of patents among leading firms is closely related to the specialized technological expertise and infrastructure of different Canadian cities. For example, Waterloo's substantial number of patents held by BlackBerry Limited demonstrates the city's focus on information and communications technology (ICT). Similarly, Toronto's high patent counts for IBM and Xerox underscore its significant contributions to cloud computing, artificial intelligence, and document management technologies. Ottawa's concentration of patents from Huawei and Nortel Networks illustrates the city's established strength in telecommunications, while Montréal's patents from Pratt & Whitney indicate its specialization in aerospace technology.

4.2 The role of multi-locational firms

4.2.1 Most significant multi-locational firms in each city

To identify the most significant multi-locational firms contributing to the technological landscape of each city, and answer the research question posed earlier on, I will conduct my analysis in two stages: The first step will be to examine the top 10 companies with the most patents within the six selected tech hubs in Canada. Afterwards, I will analyze the top five firms with the highest number of patents within each city. Through this dual-stage approach we will be able to understand both the overall influence of key players and the localized impact of leading innovators within each hub.

Starting with the first stage, the presented Table3 on the next page, provides an indication of the top five players in the technology industry within each city, based on the number of patents held:

In Calgary, the top firm is Nova Chemicals (International) SA which is a subsidiary of Nova Chemicals Corporation; a Canadian petrochemical company. Plastics and chemicals are the primary products of Nova Chemicals, and innovations in plastic manufacturing and sustainable solutions are the famous company's strengths. Nova Chemicals (International) SA is likely to be in charge of managing and overseeing the company's international operations. The company accounts for 5% of the total patents in Calgary during the 20 studies years, demonstrating being an innovative firm in petrochemical class. Calgary has four firms that hold nearly the same number of patents, ranking second

to fifth in terms of patent volume respectively as follows: Smart Technologies ULC specializes in interactive technology products and services, particularly in the education sector, providing innovative solutions for collaborative learning environments and shaping 2.3% of total patents in Calgary. Schlumberger Technology Corporation operates in the oilfield services industry, offering technology and expertise for oil and gas exploration and production and also accounting for 2.2% of total patents in the city. Known for its advanced telemetry technology, Evolution Engineering Inc. enhances the efficiency and accuracy of drilling operations in the energy industry which is known and Calgary's leading sector with this company also shaping 2.1 % of total patents. The fifth place is filled with a firm in the field of wireless communication technology, Interdigital Patent Holdings, Inc. offering advanced mobile technology solutions and filling 1.8% of total patents of city of Calgary. The notable fact here is that despite of the high level of innovation among these firms, none of them was among the top 10 firms in terms of number of patents in our selected tech hubs as presented in Figure 4.

Table 3. Top 5 firms with highest number of patents in each city

Company Name[2]	**City**	**Number of Patent**	**Share of patents in city(%)**
NOVA Chemicals (International) S.A.	Calgary	301	5.02
SMART TECHNOLOGIES ULC	Calgary	138	2.30
Schlumberger Technology Corporation	Calgary	133	2.22
Evolution Engineering Inc.	Calgary	126	2.10
INERDIGITAL PATENT HOLDINGS, INC.	Calgary	108	1.80
BLACKBERRY LIMITED	Waterloo	5437	52.27
IGNIS INNOVATION INC.	Waterloo	286	2.75
GOOGLE LLC	Waterloo	274	2.63
Rockwell Automation Technologies, Inc.	Waterloo	136	1.30
NCR Corporation	Waterloo	128	1.23

[2] Information regarding the field of operation of each firm is from: Canada, G. o. (2023). *Directories of Canadian Companies*. Retrieved 6 July 2024 from https://www.canada.ca/en/services/business/research/directoriescanadiancompanies.html

PRATT & WHITNEY CANADA CORP.	Montreal	917	6.81
INERDIGITAL PATENT HOLDINGS, INC.	Montreal	600	4.46
Immersion Corporation	Montreal	599	4.45
TELEFONAKTIEBOLAGET LM ERICSSON (PUBL)	Montreal	495	3.67
InterDigital Technology Corporation	Montreal	390	2.89
BLACKBERRY LIMITED	Ottawa	1827	10.13
HUAWEI TECHNOLOGIES CO., LTD.	Ottawa	1504	8.34
NORTEL NETWORKS CORPORATION	Ottawa	1198	6.64
International Business Machines Corporation	Ottawa	758	4.20
Alcatel Lucent	Ottawa	679	3.76
International Business Machines Corporation	Toronto	2557	8.94
Xerox Corporation	Toronto	1912	6.68
BLACKBERRY LIMITED	Toronto	1600	5.59
PRATT & WHITNEY CANADA CORP.	Toronto	861	3.01
ATI Technologies ULC	Toronto	716	2.50
THE UNIVERSITY OF BRITISH COLUMBIA	Vancouver	475	3.66
Amazon Technologies, Inc.	Vancouver	260	2.00
PMC-SIERRA US, INC.	Vancouver	228	1.75
D-WAVE SYSTEMS INC.	Vancouver	221	1.70
International Business Machines Corporation	Vancouver	193	1.48

For Waterloo however, the top firm on the list, Blackberry Limited, was also the top among all the firms located in all the studies hubs presented in Figure 4 with 5437 patents shaping almost 52% of total patents in this city. With its headquarters in Waterloo, Blackberry operates in cybersecurity software and services, as well as the Internet of Things (IoT). As the second and third most active patent holders in the Waterloo tech hub, Ignis Innovation Inc. and Google LLC stand out. In the field of IT solutions and product development, Ignis Innovation Inc. is known for its technological advancements. Meanwhile, Google LLC, a global technology giant, utilizes its extensive research and development capabilities to drive innovation across a variety of fields, including software,

hardware, and digital services. The patent portfolios of both companies contribute to the technological landscape of Waterloo, which comprises 2.7% and 2.6% of all patents in the city, respectively. The list of top firms for Waterloo ends with Rockwell Automation Technologies, Inc. and NCR Corporation. With approximately 1.3% of Waterloo's patents, Rockwell Automation Technologies, Inc. specializes in industrial automation and information solutions. Meanwhile, NCR Corporation, a provider of advanced systems for transaction processing and customer interaction, accounts for 1.2% of the city's total patents.

Pratt & Whitney Canada Corp., a distinguished Canadian aerospace manufacturer, which was the only representative from Montreal in list of top ten firms in all tech hubs, stand at the top of the list for Montreal with filling total of 6% of patents in Montreal from 2000 to 2019. This prominence emphasizes Montreal's status as a global aerospace hub, reflecting the sector's crucial contribution to the city's technological and economic landscape. There are two firms that follow Pratt & Whitney with the same number of patents and filling 4.4% of total patent of Montreal each: InterDigital Patent Holdings, Inc. and Immersion Corporation. InterDigital is widely recognized as an innovator in the field of advanced digital communications and wireless technologies, holding a number of patents relating to telecommunications and data transmission. Meanwhile, Immersion Corporation is a pioneer in the field of haptic technology, which provides tactile feedback in digital user interfaces to enhance the user experience. The next major contributors to Montreal's patent landscape are Telefonaktiebolaget LM Ericsson (publ) and InterDigital Technology Corporation. Telefonaktiebolaget LM Ericsson, known as Ericsson, is a global leader in telecommunications and networking technology, with an extensive patent portfolio in areas such as mobile networks and communications infrastructure. As a subsidiary of InterDigital, InterDigital Technology Corporation develops and licenses advanced wireless technologies, further contributing to the city's reputation as a hub of innovation.

Three firms from the top five in Ottawa have also secured spots in the overall top ten with a substantial number of patents: Blackberry Limited, Huawei Technologies Co., Ltd., and Nortel Networks Corporation. These three companies where enterprise software and

cybersecurity for Blackberry and telecommunication for the other two are the main field of focus, accounted for 10%, 8% and 6% of total patents registered in Ottawa respectively.

In Toronto, the firms leading the way with the highest number of patents are International Business Machines Corporation (IBM), Xerox Corporation, and BlackBerry Limited. These companies are not only at the forefront in Toronto but also rank among the top ten firms with the highest number of patents across the six major Canadian tech hubs. A total of 8.6%, 6.6%, and 5.5% of Toronto patents were filed by these three firms respectively. As a leading producer of cutting-edge aircraft engines and power systems, Pratt & Whitney Canada Corp. is ranked 4th among the Toronto firms with the highest number of patents accounting for 3% of total patents of the city. At the 5th location, there is ATI Technologies ULC, which is now part of AMD. This firm specializes in graphics processing units (GPUs) and semiconductors and shapes 2% of total patents in Toronto

While Vancouver firms did not made it to the top 10 total firms, The University of British Columbia stand at the first firm with the highest number of patent in Vancouver with accounting for 3.8% of total patents registered in the city. Following, three prominent Vancouver technology firms are second, third, and fourth in terms of registered patents, with a similar number of registered patents. Amazon Technologies, Inc., a subsidiary of the global e-commerce giant Amazon, harnesses Vancouver's IT talent to innovate in cloud computing, artificial intelligence, and logistics accounting for 2% of total patents in the city. A semiconductor company, PMC-Sierra US, Inc., is a leading provider of data storage, broadband communications, and networking infrastructure, contributing significantly to the city's reputation as a high-tech hub. As a pioneer in quantum computing, D-Wave Systems Inc. is on the forefront of the development of next-generation computational solutions. Both of these two firms own 1.7% of total patents in Vancouver. On the fifth spot for this city, we have International Business Machines Corporation (IBM), a leader in the field of technology and consulting.

4.2.2 Top five classes in each city and multi-locational firms contribution

In the second stage of analysis of role of multi-locational firms, Tables 3, 4, and 5 will illustrate the top five CPC classes in each city, along with the share of patents held by multi-locational firms in these locations. This analysis is s designed to provide insights

into the specific areas of technological expertise that dominate each regional innovation hub. By examining the concentration of patents within these key CPC classes and identifying the share attributed to multi-locational firms, this analysis will reveal the extent to which external knowledge and innovation influence local technological development.

Table 4. Top five CPC classes in Calgary and Waterloo

City	CPC class[3]	Class count	Share multi-locational firm (%)	City	CPC class	Class count	Share multi-locational firm (%)
Calgary	E21B	954	15	Waterloo	G06F	1273	85
Calgary	G06F	256	14	Waterloo	H04L	920	82
Calgary	H04L	181	39	Waterloo	H04W	618	93
Calgary	C08F	91	0	Waterloo	H04M	482	96
Calgary	G01V	91	23	Waterloo	H04N	304	47

The patent data for Calgary highlights the city's strong involvement in the resource extraction and energy sectors, particularly through the E21B class, which focuses on earth drilling and mining technologies. Multi-locational firms contribute 15% of the patents in this class. The second most prominent class is G06F, related to computer systems and methods, with multi-locational firms holding 14% of the patents. This reflects Calgary's advancements in data processing and computer architecture. The H04L class, dealing with the transmission of digital information, has a substantial contribution from multi-locational firms, with 39% of its patents coming from these entities, highlighting the important role of non local firms in digital communication innovations in Calgary. In contrast, the C08F class, which covers materials science innovations related to macromolecular compounds such as polymers, sees minimal involvement from multi-locational firms, suggesting a strong presence of local firms in this area. Lastly, the G01V class, focused on geophysical exploration methods for surveying and mapping subsurface

[3] The definition of each code assigned to a class as provided here was downloaded from *Cooperative Patent Classification (CPC) browser*. Espacenet. Retrieved July 10, 2024, from https://worldwide.espacenet.com/patent/cpc-browser

features, has 23% of its patents held by multi-locational firms. This analysis indicates that while Calgary has a diverse innovation landscape, certain sectors, particularly resource extraction, energy, and digital communication, are significantly influenced by multi-locational firms.

In Waterloo, the top five CPC subclasses highlight the city's strong focus on communication and computing technologies, significantly driven by multi-locational firms. The G06F subclass, covering computing systems and methods, showcases the area's advancements in data processing and computer architecture, with 85% of these patents introduced by multi-locational firms. The H04L subclass, concerned with the transmission of digital information, including error detection, data encoding, and communication protocols, also has a substantial contribution from multi-locational firms, accounting for 84% of the patents. The H04W subclass, related to wireless communication networks and technologies, shows an even higher dominance of multi-locational firms, with 93% of the patents originating from them. The H04M class, representing telephonic communication technologies, sees the highest influence of multi-locational firms, with 96% of the patents being registered by these entities, indicating the significant presence of non-local firms in this industry. Lastly, the H04N category, which includes image communication technologies such as television and digital imaging systems, has 47% of its patents introduced by multi-locational firms. This analysis suggests that Waterloo's innovation landscape is heavily influenced by multi-locational firms, particularly in the fields of computing, digital communication, and telephony, giving the city its reputation as an important center for advanced communication systems.

Table 5. Top five CPC classes in Montreal and Vancouver

City	CPC class	Class count	Share multi-locational firm (%)	City	CPC class	Class count	Share multi-locational firm (%)
Montreal	G06F	586	25	Vancouver	G06F	856	47
Montreal	H04L	448	41	Vancouver	H04L	699	37
Montreal	H04W	418	21	Vancouver	A61B	235	08
Montreal	A61B	236	18	Vancouver	H04N	225	25
Montreal	A61P	212	16	Vancouver	A61K	223	16

The patent data for Montreal reveals a strong emphasis on computing and communication technologies, with contributions from multi-locational firms. The G06F subclass, related to computing systems, has the highest patent count in Montreal, with 25% of these patents coming from firms operating in multiple locations. This suggests a robust local ecosystem for computing innovations, partly driven by external influences. The H04L subclass, concerning the transmission of digital information, has an even higher proportion of patents (41%) from multi-locational firms, indicating that Montreal is a key hub for advancements in digital communication. Similarly, 21% of patents in the H04W subclass, focused on mobile and wireless data transmission, are introduced by multi-locational firms, highlighting Montreal's role in the evolution of mobile technologies. The city's significant contributions to healthcare technology are evidenced by the A61B and A61P subclasses, with 18% and 16% of their patents, respectively, linked to multi-locational firms. A61B covers medical instruments and diagnostic equipment and A61P focuses on the therapeutic and diagnostic aspects of medical treatment and pharmaceuticals. This data suggests that Montreal's innovation landscape is not only diverse but also influenced by firms with a broader geographic presence, enhancing the city's competitiveness in both tech and healthcare sectors.

In Vancouver, the top CPC subclasses illustrate the city's diverse technological innovation landscape, with varying contributions from multi-locational firms. The G06F subclass, which covers computer systems and methods, highlights advancements in data processing in Vancouver, with 47% of the patents introduced by multi-locational firms. The H04L subclass, dealing with the transmission of digital information, such as error detection, has 37% of its patents from multi-locational firms. The A61B subclass, focused on medical technology, particularly diagnostic and therapeutic equipment, reflects Vancouver's contributions to healthcare innovation, though only 8% of these patents are from multi-locational firms. The H04N subclass, related to image communication technologies such as television and digital imaging systems, sees 25% of its patents introduced by multi-locational firms. Lastly, the A61K subclass, which pertains to pharmaceutical formulations and compositions, demonstrates Vancouver's involvement in drug development and medical research, with 16% of its patents from multi-locational firms. This data suggests that while Vancouver has a strong local presence in healthcare

technology and pharmaceutical research, the fields of computing, digital communication, and image communication are more influenced by multi-locational firms, indicating a balanced innovation ecosystem created by both local and non-local firms.

Table 6. Top five CPC classes in Ottawa and Toronto

City	CPC class	Class count	Share multi-locational firm (%)	City	CPC class	Class count	Share multi-locational firm (%)
Ottawa	H04L	2600	66	Toronto	G06F	2594.298441	60
Ottawa	G06F	1304	56	Toronto	H04L	1076.587320	50
Ottawa	H04W	1240	84	Toronto	G06Q	603.999390	32
Ottawa	H04B	627	72	Toronto	H04N	559.156062	58
Ottawa	G11C	398	69	Toronto	A61B	511.622722	14

In Ottawa, the dominant CPC subclass is H04L, which focuses on the transmission of digital information as mentioned before for other cities. With 66% of its patents coming from multi-locational firms, this subclass highlights Ottawa's significant contributions to digital communication technologies, establishing the city as a key hub for innovation in this field. The second to fifth most prominent CPC subclasses in Ottawa are G06F, H04W, H04B, and G11C. The G06F subclass, covering computing systems and methods, has 56% of its patents from multi-locational firms. The H04W subclass, related to wireless communication networks, sees a substantial 84% of its patents originating from multi-locational firms, underscoring the role of non-local firms in Ottawa's mobile and wireless data transmission advancements. The H04B subclass, which includes technologies for transmission systems and communication networks, has 72% of its patents from multi-locational firms, reflecting Ottawa's expertise in radio and television transmission development by firms located outside the area. Lastly, the G11C subclass, focused on digital storage systems like memory devices and data storage methods, has 69% of its patents from multi-locational firms. Collectively, these subclasses underscore Ottawa's broad expertise in computing, wireless communication, transmission systems, and digital

storage technologies, with a strong influence from multi-locational firms enhancing the city's innovation landscape.

In Toronto, the top five CPC subclasses highlight a diverse range of technological expertise. The G06F subclass, which focuses on computing systems and data processing technologies, has 60% of its patents originating from multi-locational firms. This can reflect the contributions made by other locations than Toronto of multi-locational firms to the promotion of computing innovation in the city. Following, the H04L subclass, covering the transmission of digital information, sees 50% of its patents from multi-locational firms, indicating robust advancements in digital communication by both local and non-local firms. As follows, the G06Q subclass, related to data processing systems for business management and financial operations, has 32% of its patents from multi-locational firms, underscoring Toronto's more important role of local firms in business and financial technology development. The H04N subclass, involving technologies for the transmission of visual information, has 58% of its patents from multi-locational firms, highlighting the city's contributions to multimedia technology. Lastly, the A61B subclass, which encompasses medical technologies, particularly diagnostic and therapeutic devices, has 14% of its patents from multi-locational firms. This broad spectrum of dominant subclasses illustrates Toronto's innovation landscape with the role of multi locational firms being considerable yet less than hubs like Waterloo.

In summary, this analysis has provided a detailed examination of the innovation landscape and specialization in Canadian technology hubs. As a result of evaluating the overall level of innovation using patent counts and their evolution , as well as assessing specialization in key technology hubs along with Revealed Technological Advantages (RTAs), we now can present a deeper understanding of the technological strengths of each hub. As well as this, the role of multi-locational firms has been examined in order to comprehend their contribution to leading areas of specialization in these cities, in addition to their impact on technological output. We will discuss these results in the next chapter, drawing conclusions and exploring implications for innovation dynamics across Canadian tech hubs as a result of these findings.

Chapter 5
Discussion and Conclusion

5.1 Discussion

Based on the results presented in chapter 4, the following arguments can be made:

One of the first key features to consider when it comes to studying concentration of innovation within the six studied tech hubs, was the number of tech-related firms present in these locations. The analysis reveals that the six hubs can be ranked as follows based on the number of tech-related firms: 1) Toronto, 2) Montreal, 3) Vancouver, 4) Ottawa, 5) Calgary, and 6) Waterloo. The more the number of players in the technology hub of the city, we can expect stronger innovation ecosystems and more robust support structures for innovation in that location. This is in line with urbanization externalities as discussed in literature review. Based on based on the work of Jacob, the variety of economic activities in an urban area can provide businesses with more potential to adopt to opportunities and challenges through more innovation, creativity and economic prosperity (Henderson, 1997). As a result, cities with a higher number of firms and consequently more economic activities can be viewed as hubs of heightened innovation. In our analysis, Toronto, with nearly double the number of firms compared to the second and third-ranked cities, exhibits the greatest potential as a focal point for new innovations.

It was also discussed by literatures that the location of firms can affect their innovation capacity. As stated by Ferreira and Fernandes (2017) , the location of an organization has a significant impact on innovation capabilities. Additionally, the paper confirms that companies with a closer geographic location to urban centers are more likely to innovate. Therefore, we can anticipate that Toronto holds the highest potential for innovation capacity.

In advancing the analysis of innovation distribution across the six targeted tech hubs, the second focal point involved assessing the total number of registered patents from 2000 to 2019, as depicted in Figure 2 of Chapter 4. This examination aimed to uncover potential correlations between the concentration of firms and their innovative outputs. According

to the results, there was no significant relationship between the volume of patents produced and the number of firms in a hub. In other words, merely having a high concentration of firms does not necessarily translate into an increase in patent activity. Based on the results of the study, Toronto and Ottawa had the highest ratio of patents to firms. This indicates that, despite differences in firm density, these cities have created an environment that is particularly conducive to innovation. Several factors may contribute to this phenomenon, including robust research and development infrastructure leading to knowledge spillover and favorable local policies aligned with the industry characteristics that can encourage patenting,

The above result was previously supported by Audretsch and Feldman (2004) where they examined the geographic distribution of innovation and concluded that while clustering of firms can encourage innovation, the mere presence of a large number of firms does not automatically lead to an increase in innovation output, such as patents. Their study suggests that knowledge spillovers, industry type, and the particular characteristics of the firms and the region have a significant impact on the level of innovation.

The subsequent analysis focused on establishing a temporal trend of new patents registered annually in each tech hub from 2000 to 2019. This examination revealed that Toronto consistently exhibited the highest annual trend in patent registrations, while Calgary had the lowest. A notable observation across all cities was the significant peak in patent activity in 2012, which marked the highest year for patent filings in Toronto, Ottawa, and Waterloo during the entire 20-year period studied. This surge in patent activity in 2012 may be attributed to a combination of factors, including favorable economic conditions, policy changes, and both local and global events that potentially stimulated innovation. The data indicates a consistent increase in patent registrations from 2009 to 2012 across all hubs, suggesting that a convergence of encouraging policies and positive economic circumstances likely played a role in this upward trend. The alignment of these factors may have created an environment conducive to innovation.

A previous paper,“ Do Economic Downturns Dampen Patent Litigation?” had also supported our results and discussed the effect of economic situation on patent registration. The Research indicates that economic downturns have significantly influenced patent

litigation rates in different ways. A decrease in GDP, particularly that caused by a decline in economic investment, has been correlated with an increase in patent litigation. The trend suggests a countercyclical pattern in which firms are more aggressive in protecting their intellectual property during economic downturns in order to secure revenue. In contrast, patent suits generally decrease during periods of increased economic uncertainty, indicating a procyclical trend. Litigation costs and financial uncertainty may deter firms from engaging in patent litigation in these situations (Marco et al., 2015).

Next, through analyzing industry specialization in six leading Canadian tech hubs, Table 2 on the previous chapter was able to determine the top 10 CPC subclasses exhibiting the highest levels of patent agglomeration. A number of noteworthy findings are revealed in this study, including Ottawa's prominent position in telecommunications, with the H04L CPC subclass demonstrating the highest concentration of patents, along with a Revealed Technological Advantage (RTA) exceeding one, indicating a clear comparative advantage in this area. On the other hand, Calgary is known for its expertise in earth and rock drilling, which is reflected in its E21B CPC subclass, which accounts for a significant portion of patents and boasts an exceptional RTA of 10.58, reflecting its inherent competitive advantage. Specialization of Cities: The Top 10 CPC subclasses with the highest portion in one city illustrate the unique specialization of each tech hub. This specialization may reflect the city’s industrial history, resource availability, or targeted economic development strategies.

The repeated appearance of the H04L and G06F CPC subclasses among the top 10 for Ottawa, Toronto, Vancouver, and Waterloo signifies a notable concentration of innovation in telecommunications and computer technologies within these Canadian tech hubs. This consistent presence across multiple cities suggests that these hubs are excelling in related technological domains, indicative of a pronounced regional specialization in these fields. The overlapping focus on telecommunications and computer technologies reflects the shared expertise, resources, and infrastructure that support these sectors across these cities. This widespread presence underscores the interconnected nature of Canada's technology landscape and highlights the critical role that these sectors play in the nation's technological advancement and competitive positioning. The pattern of specialization in

these prominent areas illustrates the significant impact of regional clusters in driving innovation and reinforces the importance of targeted technological development in maintaining a competitive edge.

This finding is inline with Porter's idea. Throughout his paper "Clusters of Innovation: Regional Foundations of U.S. Competitiveness," Michael Porter emphasizes the importance of being part of geographic clusters, which contain interconnected companies, suppliers, and institutions. Porter states that clusters are significant sources of competitive advantage for firms operating in multiple locations. It is through these clusters that companies are able to access specialized resources, expertise, and collaborative opportunities unique to their region, which contributes to productivity and innovation. The author argues that firms can gain a competitive advantage by embedding themselves in these clusters (Porter, 2001). This concept is consistent with the findings of this study, which reveal that telecommunications and computer technology, represented by the H04L and G06F subclasses of the CPC, are particularly concentrated across four out of six selected Canadian locations. The regional specialization in telecommunications and computer technologies observed across Canadian cities not only validates Porter's theory of geographic clusters but also illustrates how these local concentrations enhance competitive advantage through the RTA calculated and the proven competitive advantage of these locations.

Along with the observed specialization, the key players through firms with the highest number of patents were observed. As the data showed, the telecommunication and computer technologies were the fields that most of the top firms were operating in. With BlackBerry Limited in Waterloo and International Business Machines Corporation (IBM) in Toronto on the top of the list, we can state the existence of specialization in Toronto, Waterloo and Ottawa.

Proceeding to the next phase of the data analysis, the focus shifted to the firm level. I began by identifying the top five firms in each city to determine the key players within each tech hub. In addition to evaluating the total number of patents assigned to each firm, we also considered each firm's share of the city's total patents to assess their overall contribution. We then examined the leading CPC subclasses in each city and analyzed the

share of multi-locational firms attributed to these subclasses. By integrating these two analyses, we are able to provide a more detailed explanation of the areas of expertise within each tech hub.

Starting with Calgary, the results showed that Nova Chemicals (International) SA, a notable subsidiary of Nova Chemicals Corporation, emerges as the most significant player, contributing 5% of the total patents filed in the city. This highlights Calgary's prominent role in the broader chemical and materials science industry, underlining its specialization in this field. Following, the analysis of patent data revealed that the most influential class in Calgary is E21B, which pertains to earth drilling and mining technologies. This classification underscores the city's expertise and innovation in sectors related to resource extraction and geological applications. The concentration of patents in this class reflects Calgary's robust engagement with technologies that support and advance the energy and natural resource industries, which are integral to the region's economic foundation. Also, multi-locational firms account for 15% of the patents within the E21B class. This statistic indicates that Calgary's technological ecosystem is enriched by the contributions of firms with a presence in multiple locations, However, the role of local firms is more remarkable. The important role of local firms in innovation growth was also previously supported by Matray (2021). This research also discussed that the knowledge, expertise, and technologies produced by a prominent firm during research and development (R&D) often extend beyond the company's borders, influencing the entire community. Therefore, small and medium-sized firms and startups within the same region can benefit from spillovers of advanced knowledge and technologies, which will improve their ability to innovate.

Moving to Waterloo, the dominance of Blackberry Limited, which accounts for almost 52% of the city's total patents. This remarkable concentration of innovation within a single firm highlights the firm's pivotal role in shaping Waterloo's innovation landscape. Following, our result showed the significant presence of the G06F subclass as the class with the highest agglomeration of patents in this city. This class which focuses on computing systems and methods, underscores Waterloo's expertise in data processing and computer architecture. Notably, 85% of the patents in this subclass of Waterloo are

attributed to multi-locational firms, indicating the city's strong connections with global technology leaders. Another notable class of the city was H04M, which relates to telephonic communication technologies. This class reveals a dramatic influence of non-local firms, with 96% of patents in this category registered by multi-locational companies. This suggests that the role of multi locational firms in Waterloo is considerably high and not a considerable number of local firms play an important role in knowledge creation in this city. The benefit of non-local firms for knowledge creation of a region was also studied in a book by Isaksen (2017). It states that on-local firms bring fresh ideas, technologies, and practices from other regions, enhancing the local innovation landscape with diverse perspectives and improvements through access to a broader range of resources and markets. This is evident in the case of Waterloo, where, despite not being a major tech hub, its firms are among the key players with the highest levels of new patent production.

Moving to Montreal, the data suggest a notable specialization in the aerospace industry, with Pratt & Whitney Canada Corp. the leading firm in terms of patent activity. This dominance underscores the city's emerging as historical strength in aerospace technologies. In addition to aerospace, Montreal's tech landscape displayed a significant diversity through substantial agglomeration of its key CPC subclasses. The G06F subclass, related to computing systems, holds the highest patent weight in Montreal, with 25% of these patents coming from firms operating in multiple locations. This indicates that both local and non-local firms contribute to the level on innovation in the city. Similarly, the H04L subclass, concerning the transmission of digital information, shows an even higher proportion of patents (41%) from multi-locational firms. This suggests a growing interplay between aerospace and digital communications, as sophisticated data transmission and processing technologies become increasingly important. The presence of these agglomerated subclasses alongside the leading aerospace firm highlights Montreal's evolving and diverse innovation landscape, where traditional aerospace strengths are complemented and enriched by advancements in computing and communication technologies. This diversity in tech hub of Montreal can help it to not only foster innovation more but also adopt quicker to changing market demands and technological advancements. This was also in agreement with a study by Bilandzic et al.

(2018), where authors argue that by drawing from a broader pool of ideas and approaches, a diverse tech hub can explore a wider range of innovation pathways, reducing the risk of stagnation and increasing the potential for disruptive innovation as well as being more resilient.

Next for Ottawa, our data analysis demonstrated a strong specialization in telecommunications and enterprise software, driven by key players like Blackberry Limited, Huawei Technologies Co., Ltd., and Nortel Networks Corporation. These three firms, which are among the top five in Ottawa and also rank in the overall top ten across all studied hubs, have shaped the city's innovation landscape. Blackberry, specializing in enterprise software and cybersecurity, contributes 10% of Ottawa's total patents, while Huawei and Nortel, both leaders in telecommunications, add 8% and 6%, respectively. This concentration in specific fields is further reflected in Ottawa's most agglomerated CPC subclasses. The dominant H04L subclass, focusing on the transmission of digital information, sees 66% of its patents from multi-locational firms, underscoring the city's reliance on external knowledge sources in this specialized area. The G06F subclass, covering computing systems and methods, also shows a balanced market with 56% of patents coming from multi-locational firms. Ottawa's tech ecosystem, therefore, is characterized by a strong specialization in telecommunications and enterprise software, driven by major industry players and bolstered by balanced contributions from both local and non-local firms. This is in line with the fact that integrating both local and non-local knowledge sources is crucial for enhancing patent outcomes, as highlighted by Asheim and Isaksen (2002). Their research emphasizes the importance of combining local "sticky" information with global "ubiquitous" knowledge, which is more easily transferable and accessible across various regions and industries. This integration of local and global knowledge sources may help explain Ottawa's strong innovation performance relative to the size of its tech hub, as the city effectively leverages its specialized local expertise while also drawing on global insights to drive high levels of patent activity.

As for the Vancouver tech hub, the data characterized it by a diverse but relatively modest innovation landscape, with no dominant players significantly driving patent production. The University of British Columbia stands out as the primary contributor, yet it only

accounts for 3% of the city's patents, indicating a lack of major corporate entities leading the tech scene. The G06F subclass, which focuses on computer systems and methods, holds the most substantial weight in Vancouver's patent portfolio, with 47% of these patents introduced by multi-locational firms. This is followed by the H04L subclass, related to the transmission of digital information, where 37% of patents come from non-local entities. The influence of multi-locational firms in these key subclasses suggests that Vancouver's innovation ecosystem benefits from external knowledge sources, yet local participants are more influential based on the fact that University of British Columbia is the main player in this hub. Given the absence of major players in Vancouver's tech hub, where firms are predominantly small to medium-sized, we can draw on previous studies that suggest the interaction of innovation and knowledge among local actors and institutions in tech hubs acts as an incubator for these smaller organizations. This collaborative environment fosters growth and competitiveness within the ecosystem, enabling small and medium-sized firms to thrive despite the lack of large industry leaders (Kraus et al., 2021).

For the biggest tech hub among the six studied tech hubs, Toronto, the data showed that key players like International Business Machines Corporation (IBM) and Xerox Corporation lead in patent production, not only dominating the local scene but also ranking among the top ten firms across the six major Canadian tech hubs. The top five CPC subclasses in Toronto showcase a broad spectrum of technological expertise, with a significant emphasis on computing systems and data processing. The G06F subclass, representing these technologies, has 60% of its patents originating from multi-locational firms, reflecting the influence and contributions of these firms in driving computing innovation in Toronto. Similarly, the H04L subclass, which focuses on the transmission of digital information, has 50% of its patents attributed to multi-locational firms, highlighting strong advancements in digital communication driven by both local and non-local entities. This blend of local and global inputs underscores Toronto's dynamic tech ecosystem, where diverse technological fields thrive through a combination of local innovation and external knowledge sources. As discussed by previous studies, synergy between local innovation and external knowledge sources is key to driving growth in diverse technological fields. By effectively combining internal capabilities with external

knowledge, organizations can enhance their innovation efficiency, competitiveness, and performance in dynamic markets (Grigoriou & Rothaermel, 2016). This is aligned with the results presented for Toronto, explaining its powerful performance regarding the patent activities and being the dominant hub among the studied tech hubs.

5.2 Conclusion

In conclusion the following statements can be made for each tech hubs based on the findings of this study:

Calgary: According to our study, Calgary is an emerging technology hub with a steady growth trend primarily due to local firms that contribute the majority of new patents. The role played by multi-locational firms in Calgary's innovation ecosystem appears to be relatively small, and the overall metrics of the city, including the number of patents, the number of tech firms, and patent agglomeration, are substantially lower than those observed in the other five tech hubs analyzed. As a center for the oil industry, Calgary has the highest concentration of patents related to earth drilling and mining technologies, as well as computer technologies. This implies both the possibility of a shift and the diversification of classes present in the hub. While Calgary is still developing its stature as a major tech hub, its unique strengths and evolving specialization position it as a city with considerable potential within the Canadian tech landscape.

Waterloo: The Waterloo tech hub, though the smallest among the studied hubs in terms of the number of firms, is home to a significant player, BlackBerry Limited, which alone accounts for 52% of the city’s total patents. The hub has experienced a highly fluctuating growth trend in patent activity, with a notable spike between 2008 and 2012, followed by a decline to levels similar to 2008. This hub exhibits a significant specialization in the G06F subclass, which encompasses computer systems and methods, alongside a notable concentration in the transmission of digital information. However, the overwhelming dominance of multi-locational firms which were responsible for over 90% of patents in four out of the top five CPC subclasses, highlights the limited presence and influence of local firms. As a result of its reliance on external knowledge sources, primarily from firms with international operations, Waterloo's innovation ecosystem is particularly susceptible to vulnerability and risk, particularly in terms of sustainability and growth.

Montreal: Montreal, as the second-largest hub in terms of the number of firms, ranks third in patent output, trailing behind Ottawa. The city's patent growth has been steady over the past two decades, with no significant surges. Notably, none of the top 10 most agglomerated CPC subclasses are based in Montreal, and among the top 10 firms across all six hubs, only Pratt & Whitney represents Montreal. The city's top five CPC subclasses are diverse, with the H04L subclass, related to the transmission of digital information, seeing 41% of its patents from multi-locational firms. Overall, multi-locational firms contribute moderately to the city's patent landscape. However, the data indicate that tech industry of Montreal is characterized by diversity rather than specialization. Montreal's patents cover a wide array of sectors, including aerospace, computer systems, digital transformation, mobile and wireless data transmission, and medical instruments, highlighting the city's broad and varied technological focus.

Ottawa: Ottawa's tech industry is a standout in innovation, despite being the fourth-largest among the six studied hubs in terms of the number of firms. It ranks second only to Toronto in patent output, demonstrating the presence of highly innovative companies. The city's innovation growth has been steady, with a notable spike between 2009 and 2012. Three of the top ten firms with the highest number of patents are located in Ottawa, further highlighting its strength in innovation. While the top firm in the city, BlackBerry Limited, focuses on enterprise software and cybersecurity, the leading CPC subclasses in Ottawa is H04L, dealing with the transmission of digital information with %66 of patents coming from multi-locational firms. The most agglomerated CPC subclasses in Ottawa, such as H04L and H04W, exhibit a notable degree of overlap, sharing a common knowledge base that fosters mutual growth. This shared foundation of expertise, particularly in telecommunications and digital information, benefits from clustering effects, where the concentration of related activities enhances innovation across the board. The presence of multi-locational firms within these overlapping subclasses not only contributes to the city's specialization but also amplifies the spillover of knowledge and technology.

Vancouver: Vancouver's tech hub is the third largest among the studied cities in terms of the number of firms; yet it ranks fourth in the number of registered patents. The city has

experienced a steady, albeit modest, growth trend similar to that of Montreal, with a consistent but small increase in patent production over time. Despite the absence of major industry leaders, as shown in our data, no firm from Vancouver was among the top ten in terms of patent numbers, the city has demonstrated a comparative advantage in two highly agglomerated CPC subclasses: G06F and H04L. The G06F subclass, which accounts for 11% of Vancouver's total patents, focuses on technologies related to digital data processing, such as general-purpose digital computers and data processing systems, with 47% of these patents produced by multi-locational firms. The H04L subclass, representing 9% of the city's total patents, deals with the transmission of digital information through various communication systems and techniques, with 37% of these patents originating from non-local firms. Despite the contributions from multi-locational firms, the role of local firms is more influential in this hub, driving innovation and maintaining the city's specialization in digital data processing and communication technologies.

Toronto: It stands out as the largest tech hub in Canada, leading by a significant margin in both the number of firms and patents. It has experienced the most substantial growth among all hubs, with the most dramatic increase occurring between 2009 and 2012, likely linked to broader economic growth across Canada during that period. Toronto is home to four of the top ten firms with the highest number of patents across the six major Canadian tech hubs, including industry leaders like International Business Machines Corporation (IBM) and Xerox Corporation. The city's patent landscape is characterized by a strong concentration in the G06F subclass, focused on computing systems and data processing, with 60% of these patents originating from multi-locational firms. Additionally, the H04L subclass, related to the transmission of digital information, sees 50% of its patents attributed to multi-locational firms. Toronto's tech ecosystem is marked by its ability to leverage both local innovation and external knowledge

To address the research question, "Do nonlocal firms introduce different technologies into local innovation systems?", the data indicates that non-local firms do indeed contribute distinct technologies to local innovation ecosystems. However, the extent of their influence varies based on factors such as the size of the city and the specific industry sectors involved. In medium size tech hubs, including Ottawa and Waterloo, non-local

firms are most prominent, significantly shaping the local technological landscape. Conversely, in Toronto and Montreal, the first and second biggest hubs, the integration of local and non-local firms is more balanced, leading to a mixed technological environment that benefits from both local expertise and external innovations. In smaller hubs such as Vancouver and Calgary, local firms dominate, resulting in a greater emphasis on regionally developed technologies and less pronounced contributions from non-local firms.

Based on our results, the impact of non-local firms is particularly pronounced in sectors related to communication networks, computing systems, and data processing technologies. Non-local entities often bring advanced knowledge and innovative practices to these fields. In this variation, it is clear that both local and global knowledge flows have an important role in driving innovation and growth across different technological domains, underscoring the fact that non-local firms play a diverse role in local innovation systems.

To optimize the benefits of non-local and local firm interactions in innovation systems, tailored strategies should be developed for different-sized tech hubs. For medium-sized hubs like Ottawa and Waterloo, where non-local firms have a substantial impact, policies should focus on enhancing collaboration between these firms and local entities. Incentives for joint ventures, research partnerships, and knowledge-sharing initiatives could amplify the positive effects of non-local firms and foster a more integrated technological ecosystem. Additionally, supporting infrastructure that facilitates the exchange of ideas and technologies between local and non-local players will further strengthen these hubs.

In contrast, for larger hubs such as Toronto and Montreal, where the integration of local and non-local firms is more balanced, policies should aim to maintain and enhance this equilibrium. Strategies might include fostering an environment that supports both local innovation and external expertise, ensuring that neither is unduly favored. For smaller hubs like Vancouver and Calgary, where local firms are predominant, there should be a focus on attracting non-local firms and facilitating their entry into the market. This could be achieved through targeted incentives, support for technology transfer, and initiatives designed to increase the diversity of technological expertise within these regions.

Encouraging a greater presence of non-local firms can help to diversify the technological landscape and drive further innovation in these smaller tech hubs.

5.3 Limitation and Further Studies

One of the limitations of this study is that it focuses exclusively on six major Canadian tech hubs, which may not fully capture diversity in innovation dynamics across different geographic regions. As a result of focusing on a limited number of cities, the findings might not generalize to other tech hubs or regions, particularly small or non-Canadian ones. Further research could broaden the study's geographic scope by including tech hubs from different regions and countries. Taking this approach would provide a better understanding of how nonlocal and local firms interact and influence innovation ecosystems around the world.

In addition, there is another limitation to the study that is a result of relying on patent data as the only source of information. Patent data is valuable for analyzing formal R&D outputs, but may not encompass all innovative activities. It is possible to overlook important aspects of innovation, such as process improvements or incremental innovations. Future studies could address this by integrating additional data sources, such as innovation surveys, case studies, or qualitative interviews with firms. Using this method, we will be able to analyze innovation dynamics in a richer way and assess the contribution of both local and non-local firms in a more accurate manner.

Lastly, the study provides a snapshot of a particular point in time in the history of tech hubs' innovation landscapes, from 2000 to 2019. Dynamic innovation ecosystems undergo rapid changes. Therefore, as part of future research, we might be able to track the evolution of these ecosystems over time, using a longitudinal approach. In addition, we might be able to recognize the most recent changes in the ecosystem.

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