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The role of system-building agency in regional path creation: insights from the emergence of artificial intelligence in Montreal

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ABSTRACT

The emergence of new industries that are not closely related to existing regional paths remains an underexplained process in evolutionary economic geography. This paper responds to this gap through a case study of a maturing ecosystem of activity related to artificial intelligence in Montreal, Canada. Conceptually it brings together recent thinking in economic geography about agency in path development with complementary concepts from the literature on technological innovation systems. The empirical findings demonstrate the role of multiple agents in system-building and legitimation activities that have varied across pre-formative and formative phases of new path development in this analytical knowledge field.

KEYWORDS

technological innovation systems; emerging industry; artificial intelligence; system-building; path creation; legitimation; agency

JEL O10, O33, O38, Z31

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INTRODUCTION

The question of how and why new industries grow in certain places and not others is fundamental to economic geography. This has become a particular focus of evolutionary economic geography (EEG) approaches that have framed the problem in terms of regional path creation and development (Hassink et al., 2019; MacKinnon et al., 2019a; Martin, 2010). However, recent contributions have identified areas in which our understanding of these processes needs to be extended. These include a relative neglect of the role of non-firm organizations, institutions and public policy in new industry formation, leading to calls for a multi-agency perspective on regional path development (Hassink et al., 2019; Steen, 2016). A strong theoretical and empirical emphasis on path branching also means the emergence of new industries unrelated to established regional industries are not as easily explained within current EEG frameworks (Boschma et al., 2017; Grillitsch et al., 2018).

Both of these concerns can be engaged with through a focus on the development of new industries driven by advances in scientific knowledge. The *analytical* knowledge base of these industries underpins different patterns of innovation and path development to industries characterized by learning through the application and combination of existing *synthetic* knowledge (Asheim & Coenen, 2005). In analytical knowledge base industries, the core path-creation mechanisms and agents relate to the role of universities or other research organizations in the generation or acquisition of scientific knowledge, and of new enterprises (e.g., academic spin-out firms) in converting this knowledge into commercial products or services (Isaksen & Trippl, 2017). The forms of basic research performed by these universities or other public organizations are often in scientific or technological domains that are not closely tied to the industrial

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capabilities of the region in which they are located (Vallance, 2016). Processes of unrelated path development cannot, however, be reduced to a linear model of scientific research commercialization. Recent contributions to the literature have emphasized that these processes require varied forms of agency within the region to form the market and institutional conditions that enable the introduction and adoption of new technologies (Boschma et al., 2017; Carvalho & Vale, 2018). There is, therefore, a need for a deeper appreciation of the dynamics and challenges that this more radical form of regional path creation involves from an evolutionary standpoint that explores institutional agency and system development.

This paper responds to this gap through a case study of the emergence of Montreal, Canada, as a globally significant artificial intelligence (AI) hub. We interpret AI as an incipient general-purpose technology derived from academic breakthroughs in computer science with applications across a range of existing and new industries. This is manifested in Montreal as a maturing ecosystem of concentrated research and commercial activity that constitutes a new path for the regional economy. Informed by the nature of the analytical knowledge base involved, we develop a framework that combines regional path development theories with complementary concepts drawn from the literature on technological innovation systems (TIS). This TIS literature is valuable here in providing insights into the evolution of new technological fields as an outcome of the interplay of multiple actors engaged in processes of system-building and related institutional work to legitimize technological systems (Musiolik et al., 2018). The identification of specific activities involved in this system-building allows for a more detailed conceptualization of different phases involved in the regional path-creation process. The overall objective is to identify and analyse the dominant system-building functions undertaken by different actors in the pre-formative and formative phases of TIS formation to support its emergence and legitimation as a new path for the regional economy. This can be divided into two interrelated research questions that guide our analysis:

- How has the role of different actors in the Montreal AI ecosystem (including non-local actors) varied across the different system-building phases?
- How has legitimacy been built up through the institutional work and interplay of different actor groups?

Accordingly, the case study is focused on deepening our understanding of how the role of different agents from within and outside the region has changed across these early stages of Montreal becoming a scientific and industrial centre for the technological field of AI. Specifically, we focus on the role of three key types of actors, namely *trailblazers*, *anchors* and the *state*. Trailblazers refer to pioneering actors with a fundamental role to the development of AI in Montreal, including star scientists, venture capital firms (VCs) and AI start-ups; anchors include universities, public research laboratories (PRLs) and large firms/multinational enterprises (MNEs) that mobilize intra- and extra-regional resources and serve as 'key sites of knowledge production and workforce training' (Spigel & Harrison, 2018, p. 155); and the state represents the government at different scales of intervention. The findings highlight the role of these actors across two phases of system-building: a long pre-formative phase characterized by distributed and uncoordinated agency, followed by a more strategic formative phase of intense development and legitimation efforts. It shows that the role of some of the actors has evolved from one phase to the other, while others strengthen their position as anchors in a dynamic process of system-building with shifting demands.

The remainder of the article is structured as follows. The next section explains the theoretical background and analytical framework. The third section outlines the methodology. The fourth section presents the findings in relation to system-building and legitimation activities. The fifth, concluding, section discusses the findings and key contributions of the paper.

THEORETICAL BACKGROUND AND ANALYTICAL FRAMEWORK

Agency in regional path development

A growing area of enquiry for EEG is the ways in which new paths develop in regional economies. These processes of change have to be considered against opposing forces towards continuity or stasis in regional industrial, technological and institutional structures foregrounded by the concept of path dependence (Martin, 2010). One common approach to resolving this conceptual tension has been to concentrate on 'branching' from existing industries into newer paths founded on related knowledge or technologies (Neffke et al., 2011). Hence, case study research in EEG has often focused on emerging paths that draw on engineering capabilities and infrastructural assets formed as a legacy of previous manufacturing activities in old industrial regions (e.g., MacKinnon et al., 2019b). This diversification into related areas often works in conjuncture with other means of path development, such as the technological upgrading of traditional industries or the transplantation of new knowledge or practices from outside the region (Martin & Sunley, 2006).

A newer strand of this literature has, however, begun to explore the potential for more radical forms of path diversification into unrelated domains (Boschma et al., 2017; Grillitsch et al., 2018). This can take the form of combinations of knowledge or technologies that are not closely related. For instance, the introduction of new analytical knowledge into industries with a predominately synthetic knowledge base (Grillitsch et al., 2018; Tanner, 2014). Alternatively, some domains of analytical knowledge can themselves be commercialized to form the basis for new indigenous paths in science or technology-based fields (e.g., biotechnology, information and communication technology – ICT) that are only weakly related to

established industries in the region (Isaksen & Trippl, 2017; Martin & Sunley, 2006; Vallance, 2016). Previous research has, however, demonstrated that these forms of analytical knowledge that originate from universities or public research organizations only translate into significant regional development outcomes when enabled by a wider innovation/entrepreneurial ecosystem of favourable institutional and market conditions (Marques et al., 2019). For highly novel technologies, these enabling conditions will not already be present in many regional contexts and will need to co-emerge with the entry of new firm actors (e.g., new start-up enterprises, external investors). The challenges involved in realizing this route towards new path creation therefore mean the broader evolutionary dynamics behind it need to be closely interrogated.

The reasons for the genesis of new economic paths in certain places and not others has, in theories of path dependency, been ascribed to 'historical accident' – serendipitous events or favourable preconditions that stimulate the initial activity from which a path arises and over time becomes 'locked-in' through self-reinforcing growth effects such as agglomeration economies (Martin, 2010; Martin & Sunley, 2006). Recent work has, by contrast, become interested in the role of agency of different types in intentionally encouraging and shaping path development (Grillitsch & Sotarauta, 2019; Hassink et al., 2019; Steen, 2016). This marks a broader perspective than earlier EEG frameworks that focused on populations of firms as the agents of economic evolution, and represented their agency in the form of competition, innovation, and spin-off activity that led to the development and transfer of more efficient organizational routines within a region (Boschma & Frenken, 2011). For instance, contributions have highlighted the function of state and policy actors at multiple scales in creating favourable institutional conditions for path creation and/or intervening to support promising new industries or technologies (MacKinnon et al., 2019a; Tödtling & Trippl, 2018). As part of a geographical political economy perspective, the 'strategic coupling' of transnational corporations is also identified as a mechanism of path development in many territorial contexts (MacKinnon et al., 2019a, 2019b). This example of non-local agency highlights the role that exogenous resources and knowledge can play within these processes (Trippl et al., 2018). In addition, the central position of universities and public research organizations as sources of new knowledge in regional innovation systems means they are also beginning to be recognized as actors within regional path development (Carvalho & Vale, 2018; Tanner, 2014; Vallance, 2016).

Taken together, this work points towards the potential to build a *multi-actor* and *multi-scalar* conception of path development in economic geography (Hassink et al., 2019). This project will, however, require a deeper understanding of how these diverse organizational actors interact with each other at the level of a territorial system. For Garud and Karnøe (2003), agency in transforming a technological (rather than regional) path is distributed across multiple actors whose varied involvement in this process is nevertheless shaped by their mutual embeddedness in the context of relations, practices, and knowledge generated by the unfolding path. This perspective is extended by Isaksen et al. (2019) who, in reference to regional path development, propose a distinction between distributed entrepreneurial agency at the level of individual firms and system-level agency that is oriented towards being 'able to transform regional innovation systems to better support growing industries and economic restructuring' (p. 52). Similarly, Grillitsch and Sotarauta (2019) identify the complementary notion of institutional entrepreneurship as one form of agency that can drive regional path development (alongside Schumpeterian innovation entrepreneurship and place-based leadership). Institutional entrepreneurship refers to deliberate agency aimed at transforming or replacing existing institutions, which has been emphasized as a key dynamic in overcoming path dependency and hence enabling regional economic change (Boschma et al., 2017; Sotarauta & Suvinen, 2018).

System-level agency in path creation is related to the process of system-building that has been developed in work on TIS. This concept, however, goes further by not just considering how the existing institutional structures of an innovation system can be adaptively transformed by embedded agents, but also by emphasizing that these structures can be strategically created through collective agency (Isaksen et al., 2019; Musiolik et al., 2012). This less static view of an innovation system has already been drawn upon in economic geography by Binz et al. (2016b) who, in the context of on-site water recycling in Beijing, show that new industry formation and local path creation emerge from cumulative TIS-building processes. These processes draw on resources (knowledge, niche markets, technology legitimacy and financial investment) that are developed through the systemic interplay between actors, networks and institutions in an evolving TIS. In this paper we propose that these forms of system-building are especially pertinent to cases of regional path creation through the emergence of new analytical knowledge base industries. The next subsection will therefore explore this TIS literature in more depth with particular reference to how system-building concepts can be applied in multi-scalar territorial settings to help explain the genesis and growth of a regional path based on an advanced technological field.

System-building: the TIS perspective

The TIS literature provides a framework for understanding the functioning of an innovation system in terms of the development, diffusion and use of a technology (Bergek et al., 2008a, 2015). A TIS is defined as 'a set of elements, including technologies, actors, networks and institutions, which actively contribute to the development of a particular technology field' (Bergek et al., 2015, p. 52). As in a territorial innovation system, actors include firms, universities, research institutes, financiers, industry associations and government bodies (Musiolik et al., 2012). Also referred to as 'system-builders' in the TIS literature, they are 'actors who are technically, financially and/or

politically so powerful that they can initiate or strongly contribute to the development and diffusion of a new technology' (Jacobsson & Johnson, 2000, p. 630).

TIS actors are involved in various processes known as functions. This paper refers to six core functions identified by Binz et al. (2016b): knowledge creation and diffusion, resource mobilization, market formation, influence on the direction of search, entrepreneurial experimentation, and legitimation. These are summarized in Table 1. In an emerging technological field, they are often the product of distributed agency, forming key resources that help actors advance a new path (Binz et al., 2016b; Musiolik et al., 2012). These functions do not exist in isolation but 'are closely linked and coupled in cause–effect chains' (Bergek et al., 2008b, p. 580). This is especially important in the case of legitimation (Binz et al., 2016a). As Bergek et al. (2008b) argue, technology legitimation is both a prerequisite for and a result of TIS formation, being a cumulative process driven by the accumulation of actors, familiarity with the new technology and trust in the various TIS actors.

Nevertheless, the analytical focus on system functions can detract from the critical role of agency in system-building (Musiolik & Markard, 2011). With much of the TIS literature focusing on macro-level dynamics, there is an underemphasis of the agency of 'system-builders' in TIS development (Binz et al., 2016a), especially in terms of how resources are developed or strategically deployed by actors to form TIS structures, how different means of TIS formation unfold in different development phases and how system-builders proceed in different settings (Musiolik et al., 2012, 2018). Similarly, with empirical TIS studies often conflating legitimation with overall system development, there remains a lack of understanding of how legitimacy is actively built up through the interplay of different actor groups in the early stage of a new technology and regional industry (Binz et al., 2016a).

More recent studies focusing on institutional work and agency have highlighted legitimation as a continuous interplay between institutions, actors and technologies (Fuenfschilling & Truffer, 2016). This means that, as with the institutional entrepreneur concept, actors can deliberately change institutional structures within which they are operating to legitimize a new technology (Musiolik & Markard, 2011). Indeed, if a new technology is to diffuse, the relevant institutional context needs to be aligned to the new technology (Bergek et al., 2008a; Binz et al., 2016b; Hekkert et al., 2007). This is not an automatic process but needs conscious agentic effort (Bergek et al., 2008b). As many new technologies are faced with a 'liability of newness' (Zimmerman & Zeitz, 2002), often being in conflict with prevailing institutions (Binz et al., 2016a), conscious institutional work by individual and collective actors to create new institutions or transform existing ones is critical to overcome this (Musiolik et al., 2018).

Legitimation as institutional work is intertwined with other system-building functions at different phases of TIS development. Binz et al. (2016a) provide a framework that enables a more granular analysis of institutional work that disentangles legitimation processes from system maturation. It identifies three legitimation phases – innovation and local validation, diffusion, and general validation – highlighting how actors engage in different types of institutional work at different stages of TIS development and how these interact with broader system-building processes over time. We employ this lens to analyse legitimation efforts in the case of Montreal's emerging AI ecosystem. By situating this new technological path within a specific territorial context, these legitimation phases also become a geographical process of institutional formation drawing on local and non-local resources.

Agency in a TIS also manifests in the form of wider system-building strategies employed by actors to advance a new technology. Musiolik et al. (2018) distinguish between emergent system formation, which occurs without much coordination through distributed agency, and strategic system-building where an organized actor community acts strategically to develop the TIS. The two are not mutually exclusive but coexist and vary with TIS development phases. Furthermore, a TIS can exist at different maturity levels, with each influencing its specific configuration and the importance of different functions (Markard & Truffer, 2008). Bergek et al. (2008a) distinguish between a formative and a growth phase. In the formative phase, an emerging TIS typically lacks specialized components and is characterized by large uncertainties with regard to technology applications and markets, a small volume of economic activities, significant entrepreneurial experimentation, and unarticulated demand (Bergek et al., 2008a, 2008b). If the TIS is able to 'shift gear' and sustain itself, it enters a growth phase of system expansion and wider technology diffusion (Bergek et al., 2008b). Binz et al. (2016a) also identify a pre-formative TIS phase (i.e., innovation and local validation) typically characterized by 'lighter' institutional work such as theorizing and changing normative associations. If successful, diffusion in the formative stage will require more substantial legitimation work to become established as an alternative.

The TIS framework is particularly suited for studying system-building in the development of emerging and radically new technological fields such as AI (Hekkert et al., 2007; Musiolik et al., 2012; Musiolik & Markard, 2011). As argued above, this also means it is potentially valuable to understanding the creation of new regional paths centred on these technologies and their associated analytical knowledge bases in economic geography. In particular, the role of different types of actors within this form of path development can be elucidated through a focus on their agency in processes of system-building and institutional legitimation. This paper will empirically demonstrate this theoretical contribution by examining the role of different agent groups (e.g., universities, federal and provincial governments, start-up and MNEs) in the development of a vibrant AI ecosystem in Montreal. The

Table 1. Summary of technological innovation system (TIS) functions.

Function	Description
Knowledge creation and diffusion	The breadth and depth of a formal knowledge base; how knowledge is developed, diffused and combined in the TIS. New technological knowledge-creation activities through different learning processes (e.g., learning-by-searching, learning-by-doing) and facilitation of information exchange among actors
Resource mobilization	Activities involving the mobilization of human and financial capital and complementary assets from other sources than suppliers and users
Market formation	Activities contributing to the creation of a demand or a protected space for the new technology; stimulating the emergence of markets for new products
Influence on the direction of search	The incentives for supply-side actors to enter the TIS and direct their search and investments towards the TIS. Activities that may influence further investments in the technology
Entrepreneurial experimentation	More tacit, explorative, applied and varied knowledge creation involving technical experiments, testing, and the development of new applications and markets that leads to the discovery/creation of new opportunities
Legitimation	Conscious actions that contribute to the social acceptance of the technology and the actors and compliance with relevant institutions, such as counteracting resistance to change or contributing to taking a new technology for granted

Sources: Adapted from Bergek et al. (2008a, 2008b); Musiolik and Markard (2011); and Hellsmark et al. (2016).

combination of local, national and multinational actors that are involved in these processes will also highlight the multi-scalar nature of regional path development (Hassink et al., 2019; MacKinnon et al., 2019a; Trippl et al., 2018). The next section outlines this empirical focus and methodological approach.

METHODOLOGY

The empirical focus is the region of Montreal in Québec province, Canada. Home to universities with the biggest concentration of academic researchers in deep learning in the world (Turkina, 2018), a growing start-up scene and an increasing number of global technology players, Montreal has developed a thriving AI 'ecosystem' (Fox et al., 2018; Montréal International, 2019). Therefore, the region provides an ideal case study for examining the emergence of AI as a new analytical knowledge-based regional path.

To achieve the study's aim, a mixed-methods approach was employed. A total of 32 in-depth semi-structured interviews were conducted with a range of stakeholders from Montreal, including academia, industry and government representatives (Table 2). The interviews focused on understanding what sparked the development in AI in the region, the actors involved in the TIS, the involvement of different 'system-builders' and challenges for further development. The interviews were triangulated with relevant documents, reports and online publications relating to the AI scene in Montreal specifically, and Canada more broadly, to identify key events, milestones, and policies geared at supporting the technology and its industrial applications. This corroborated the insights from interviews and enriched the understanding of the study's context.

Both in-depth interviews and qualitative content analysis are particularly suitable for facilitating an actor-based understanding of early stage TIS and early industry formation (Bergek et al., 2008a; Binz et al., 2016b). The interviews followed a semi-structured format, allowing a degree of flexibility and probing of additional issues that surfaced during the interview. The participants were selected through a combination of purposive and snowball sampling, commonly used in qualitative research and TIS studies (Bergek et al., 2008a; Robinson, 2014). The interviews were conducted in April and May 2018 during an extended field stay and were recorded and fully transcribed. The transcripts were subsequently coded following an open-coding strategy, facilitating analysis through the constant comparative method whereby recurring themes were identified (Boeije, 2002). It was a stipulation of the research that the participating individuals remained anonymous. As such, interviewees are numbered chronologically.

FINDINGS: AI PATH CREATION THROUGH SYSTEM-BUILDING

The empirical part of this paper will show that the AI 'ecosystem' in Montreal is the outcome of a long process involving a combination of uncoordinated and strategic agency intertwined with system-building activities throughout the pre-formative and formative system-building phases. Table 3 maps the system-building activities to which the different local and non-local actors contributed during the two phases and the types of institutional work they undertook. We will unpack these in the following sections and highlight their evolution throughout the two phases.

Table 2. Profile of respondents.

Respondent	Organization type	Role
INT1	Support services	Co-founder and partner
INT2	Academia/research	Director of research
INT3	Accelerator/incubator	Chief innovation officer
INT4	AI start-up	Founder and CEO
INT5	AI start-up	Founder and CEO
INT6	Co-working space	Co-founder
INT7	AI start-up	Co-founder and director
INT8	Large firm	Manager
INT9	AI start-up	Co-founder and COO
INT10	AI start-up	Co-founder and CTO
INT11	AI start-up	Founder and CEO
INT12	Venture capital firm	Partner
INT13	AI start-up	Head of growth
INT14	Venture capital firm	Co-founder and partner
INT15	AI start-up	Founder and president
INT16	AI start-up	Co-founder and CTO
INT17	AI start-up	Founder and CTO
INT18	AI start-up	Chief science officer
INT19	Large firm	Research scientist
INT20	Government/economic development agency	Director
INT21	Large firm	Senior director
INT22	Government/economic development agency	Innovation officer
INT23	Government/economic development agency	Science innovation officer
INT24	Government/economic development agency	Innovation officer
INT25	AI start-up	Founder and CEO
INT26	AI start-up	Co-founder and CTO
INT27	Accelerator/incubator	Associate director
INT28	AI start-up	Founder and CEO
INT29	Academia/research	Professor
INT30	Academia/research	Professor/AI researcher
INT31	Non-governmental organization	Co-founder
INT32	Accelerator/incubator	Director of operations

The pre-formative phase: from serendipity to distributed agency

The role of serendipity in the emergence of AI as a new path in Montreal was prominent in the responses of interviewees, who highlighted that the mix of researchers, universities and the availability of public funding for research created 'the perfect storm of things' (INT1). With these elements 'brewing for a while' (INT16), many shared the view that 'it just happened' (INT2) and that 'there has always been this presence of AI, but it hasn't been mainstream' (INT16). Indeed, ever since 1955 when McCarthy coined the term 'artificial intelligence', developments in AI occurred in waves, with multiple so-called AI 'winters' when research, funding and interest declined significantly. However, progress in computer science, increases in computational power and the availability of huge datasets stimulated a resurgence in the early 2000s, making this the beginning of 'a modern wave of AI revolution' (INT19). In Montreal's case, it was a small number of key actors – *trailblazers*, *anchors* and the *state* – that contributed to the emergence of AI.

The pre-formative phase, which corresponds to innovation and local validation (Binz et al., 2016a), is in this case marked by its long duration. Decades of distributed effort were required to create the pre-formative structures and resources that subsequently spurred the development of the TIS. In Montreal, 'it started with strong academics' (INT18) within universities and PRLs, which were instrumental in advancing the field through scientific research. They played a central role as *trailblazers* in creating new analytical knowledge that now underpins the field. One of those is Yoshua Bengio, a pioneer in deep learning

Table 3. System-building and institutional work by technological innovation system (TIS) actors in Montreal.

	Innovation and local validation (pre-formative phase)		Diffusion (formative phase)	
Agent	**System-building**	**Institutional work**	**System-building**	**Institutional work**
The state	Resource mobilization, legitimation	Valorizing	Market formation, influence on the direction of search, entrepreneurial experimentation, legitimation	Political work, valorizing, constructing normative networks
Universities/public research laboratories (PRLs) (including star scientists)	Knowledge creation and diffusion, legitimation	Theorizing, changing normative associations, constructing normative networks	Knowledge creation and diffusion, resource mobilization, legitimation	Theorizing, advocacy, changing normative associations, educating, valorizing, constructing normative networks
Venture capital firms	Resource mobilization, market formation	–	Resource mobilization, market formation, legitimation	Valorizing
Artificial intelligence (AI) start-ups	–	–	Entrepreneurial experimentation, knowledge creation and diffusion, legitimation, influence on the direction of search	Advocacy, changing normative associations, constructing normative networks
Large firms (multinational enterprises – MNEs)	–	–	Legitimation, entrepreneurial experimentation, knowledge creation and diffusion, resource mobilization, influence on the direction of search	Advocacy, educating, theorizing, valorizing, changing normative associations, constructing normative networks

whose work was central in establishing Montreal as an international AI hub:

> You had a very small group of people, like Yoshua Bengio and multiple of his students, that have been [researching AI]. Decades ago, before machine learning, before all the networks were trendy, those people were believing in it, even at a point where it was not generating any money. … They are the people who ultimately really started what we have now.
>
> (INT4)

In 1993, Bengio founded the Montreal Institute for Learning Algorithms (MILA), creating a small network of AI researchers. The formation of this network represents the crystallization of previously disparate research efforts in the then unpopular AI arena and the first in a series of developments that ultimately led to breakthroughs. As such, the year can be taken as the starting point of the embryonic TIS in Montreal. Trailblazing through a period of uncertainty and loss of interest in AI, the institute has yielded significant scientific contributions in deep learning. A key breakthrough was made in 2006 in neural networks, rebranded as deep learning in a pioneering paper by Geoffrey Hinton – one of Bengio's key collaborators – and colleagues (LeCun et al., 2015). As shown in Figures 1 and 2, this generated a wave of theorizing and revived interest in AI, placing MILA at the epicentre of subsequent breakthroughs. The revolutionary nature of deep learning involved changing normative associations, which was facilitated by the collaborative work within the research community. Through MILA, Bengio created the first normative network in this subfield, which included Hinton and Yann LeCun – the other two figures known as the 'godfathers' of deep learning – and many of their students.

Critical for Montreal was the determination of this small group of researchers led by Bengio to continue doing research and not leave academia. As the interviewees highlighted, '[Bengio] could've named his price anywhere in the world' (INT20) but 'declined crazy offers to work in the US and other countries, because he wanted to build something really meaningful here' (INT4), making it his mission to develop the next generation of AI researchers in Montreal. As a *trailblazer*, he fundamentally influenced the emergence of AI and formation of an embryonic TIS through knowledge creation and diffusion in these early days. This resonates with previous studies that have highlighted the role of 'star scientists' in the development of clusters in analytical knowledge industries such as

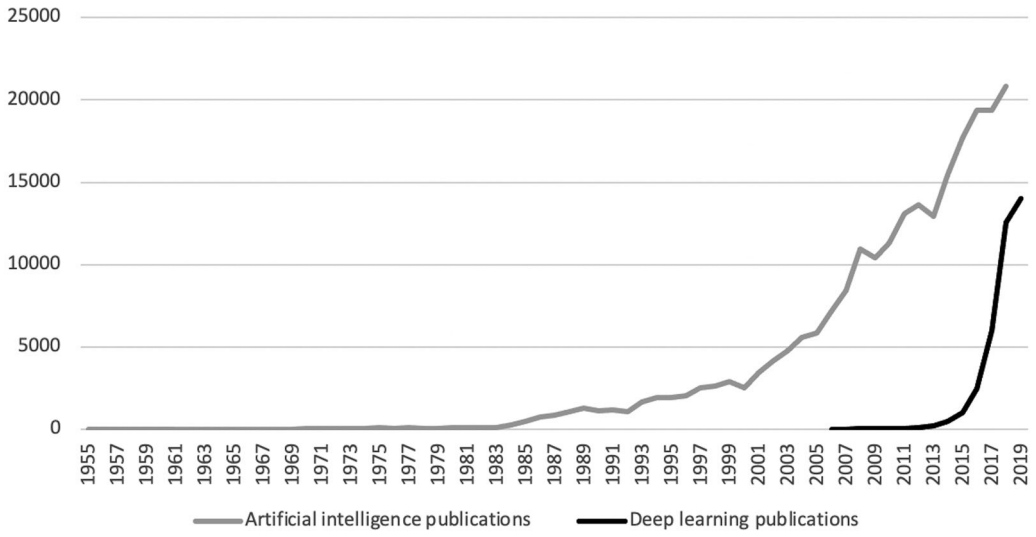

Figure 1. Artificial intelligence (1955–2018) and deep learning (2006–19) publications in computer science journals.
Source: Scopus (https://www.scopus.com).

biotechnology (Zucker & Darby, 1996). However, where this literature emphasizes the geographical and organizational mobility of these star scientists (Trippl, 2013), throughout this long pre-formative phase of the Montreal AI ecosystem their agency was more closely related to their decision to remain in the same institution and region.

Nevertheless, the work of these pioneers would have not been possible without sustained public funding from the Canadian government in the form of research grants. This early mobilization of resources by the federal government was instrumental in enabling the scientists to continue their research activities, which kept them in academia as many 'would probably not have stayed in Canada if they had no funding' (INT15). As an interviewee explained: 'The Canadian government funded the AI research even when no one absolutely around the globe was interested in it' (INT19).

Therefore, the *state* at the federal level acted as a key enabler, supporting the emergence of AI by funding basic research.[1] An important government-funded organization that kept research in neural networks alive during the AI winters of the 1980s and 1990s was the Canadian Institute for Advanced Research (CIFAR),[2] 'where all the three godfathers of the deep learning worked … and paved the road to what is now known as the AI revolution' (INT19). It was programmes such as Artificial Intelligence, Robotics & Society (founded in 1983) and Neural Computation & Adaptive Perception that funded star scientists throughout those early years. A critical aspect was that research grants were not tied to business objectives, which enabled the researchers to do 'research for the sake of research, not necessarily for any commercial purpose' (INT27). This is underpinned by the belief that 'the best way to fuel

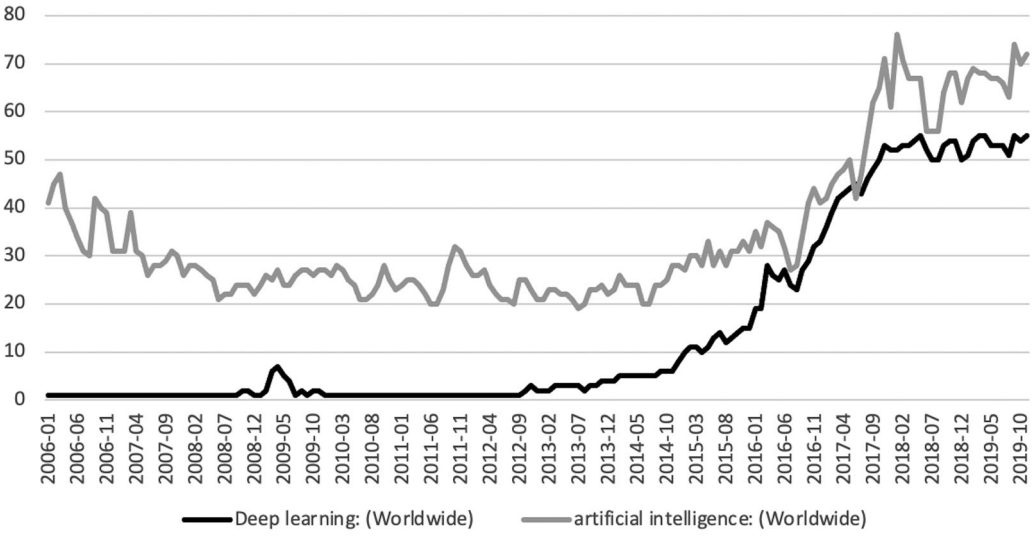

Figure 2. Google search interest in deep learning and artificial intelligence, 2006–19.
Source: Google Trends (https://www.google.com/trends).

innovation is to support fundamental research' (CIFAR, 2019, n.p.):

> If your project is interesting and innovative, you get the money. … It doesn't need to be tied to a business objective, so because of that there were a few researchers in Canada … [who] were able to keep doing research even though it wasn't hot.
>
> (INT14)

While the breakthroughs could not have been predicted, and therefore an element of serendipity needs to be acknowledged, the *state*'s approach to funding exploratory scientific research can be identified as a major catalyst to path creation (Vallance, 2016). By providing critical funding, the *state* played an active, albeit unconscious, role, valorizing early AI research:

> The government didn't say twenty years ago, 'AI will be important in twenty years' … but the approach of letting people research what they want paid off.
>
> (INT14)

Another actor identified in this embryonic TIS is a VC firm whose early involvement, albeit not directly connected to AI, laid the foundations for entrepreneurial experimentation. Establishing in Montreal in 2007 when the region was characterized by a weak entrepreneurial scene, the VC set on a mission to build an entrepreneurial ecosystem. This started with a seed fund of C$5 million, followed by a second fund of C$50 million to support start-ups. The VC also launched an accelerator programme for early-stage start-ups, started building international links, and used part of the funds to build impactful projects, including what is now one of the main start-up hubs in Montreal:

> When we started investing in Montreal, Montreal did not have a strong start-up ecosystem, so we chose to focus on the market and help build that. … We also focussed on entrepreneurs that wanted to make a difference, more impactful projects with global aspirations.
>
> (INT14)

Mobilizing resources, they built the flagship infrastructure to support entrepreneurship in the region, which makes the VC a 'hidden' *trailblazer* in the embryonic TIS. Their commitment to 'building' Montreal and success of early investments generated the financial capital that subsequently enabled entrepreneurial experimentation in AI:

> About ten years ago, when they came to Montreal, there was no seed funding here … [so] they started a seed fund … [and] changed the face of Montreal.
>
> (INT20)

> [The VC] has been a true catalyst in getting the [AI] ecosystem to where it's at now.
>
> (INT12)

Therefore, the development of system structures in the pre-formative phase was the result of distributed agency (Musiolik et al., 2018), with a small number of actors contributing to early system-building, albeit in an uncoordinated way. With interest in AI confined to small research circles during this period, institutional work was limited to theorizing, changing normative associations and constructing normative networks. The embryonic TIS was built on knowledge creation and diffusion with the support of public funding, while private efforts paved the way for growth in the formative phase.

The formative phase: from distributed to deliberate agency

The ecosystem 'shifted gear' around 2016, entering a formative phase described as an 'AI hype' characterized by intense entrepreneurial experimentation, the agglomeration of (new) actors, and greater investment that propelled Montreal onto the global AI scene. The actors and resources leveraged during this phase of system-building are also increasingly from outside as well as within Montreal, demonstrating the multi-scalar nature of the path development process. The start of this phase was marked by the establishment and rapid expansion of Element AI, which quickly became the fastest growing AI start-up in the world (Turkina, 2018), and by the opening of research labs by tech giants seeking to establish their presence in the increasingly popular ecosystem. As an interviewee explained, '2016 was around the time when the Montreal ecosystem started to activate in AI' (INT6). This phase is seeing a combination of developing, distributed and deliberate agency, with TIS actors adopting a more strategic approach to system-building through partnering (Musiolik et al., 2018). As an ongoing diffusion phase (Binz et al., 2016a), it is marked by key landmarks and increased legitimation efforts.

Starting with 2016, Montreal has seen a proliferation of AI start-ups – a new set of *trailblazers* leading entrepreneurial experimentation through the development of commercial applications of AI. As an interviewee emphasized, 'we're seeing this next step now in the emergence [of the ecosystem], which is AI start-ups' (INT26), with 'tons and tons and tons of AI start-ups booming in Montreal' (INT3). The most notable is Element AI, co-founded by Yoshua Bengio with significant traction and support from the private sector, whose formation and early success 'pushed the Montreal [AI] ecosystem into really activating itself' (INT16). Raising a total of C$337.5 million, million, a landmark that cemented Montreal's' position on the global AI scene, Element AI sparked an entrepreneurial hype which contributed to legitimizing the TIS: '[Element AI] put us on the world map' (INT15). This early success is the result of existing and new TIS actors coalescing more formally and mobilizing resources for entrepreneurial experimentation, with investors including the provincial government, VCs, and international investors. Critically, it catalysed the flow of private capital into AI, with more than C$2 billion in AI investments announced in the region since 2016 (Montréal International, 2019) and new AI-focused VCs entering the scene.

Among the investors is the aforementioned VC company that helped create an entrepreneurial ecosystem in the region. The firm is instrumental to Element AI's success, being the leading regional private actor that made an early case for investing in AI: 'They came up with a thesis of investing massively in AI and that spawned Element AI.' (INT12). Moreover, within the decade that it took AI to take off in Montreal, the VC worked on building links between academia, government and industry, using AI as a platform for solidifying relationships within the TIS and fostering collaboration among system-builders:

> We wanted to build a bridge between governments and large organisations and universities in the start-up ecosystem, so we focussed on AI as a great technology to help build that bridge because we see AI as the next-step platform to drive significant value creation going forward.
>
> (INT14)

Making an early bet on AI, it was among the first VCs that 'allocated the majority of its current funds to investing in AI-based start-ups' (INT1), growing to manage more than C$330 million. Thus, if *the state* catalysed AI innovation in the pre-formative phase, VCs propelled it to the next level by enabling entrepreneurial experimentation: 'because there's capital available now, it's spurring a lot of start-ups in that [AI] space' (INT3). In a positive domino effect, the increase in AI investments is giving rise to AI-focused incubator programmes that provide critical early-stage support to entrepreneurs. Importantly, VCs' early role as *trailblazers* is slowly morphing into *anchors* as AI investments and VC-backed support programmes increasingly attract both local and international entrepreneurs and researchers to Montreal, helping secure much needed entrepreneurial and AI talent.

Furthermore, drawn by Montreal's concentration of AI expertise, a number of major U.S. technology corporations started to open AI labs in the city shortly after Element AI was launched. Among the first were Google, Microsoft, IBM and Facebook, who then attracted others, with many employing leading AI researchers to head their labs. Their arrival signalled Montreal's potential, legitimizing system-building efforts by local actors: 'When the [big players] started showing up in town, that really gave credibility and rise to the ecosystem' (INT3). Importantly, they started contributing to system-building by partnering with existing actors: 'a lot of them are starting to build residency programmes … where you get your PhD while working in some of those big shops … [which] helps to feed the next generation of talent' (INT3). Many have also made substantial investments in Montreal's academic and entrepreneurial communities. For example, Microsoft contributed US$ 7 million to the University of Montreal and McGill University and is an early investor in Element AI, while Google granted C$4.5 million to MILA. Such extra-regional actors therefore help to both create and *anchor* resources, contributing strategically to knowledge creation and diffusion through resource mobilization and entrepreneurial experimentation, and to reinforce legitimation efforts through educating, valorizing, and changing normative associations via research into new applications of AI.

Importantly, this bridge between academia and industry is facilitated by the fact that many leading AI researchers are able to split their time between the two, with many heading private research labs or being involved in start-ups. Again, echoing the findings of earlier studies of star scientists (Zucker & Darby, 1996), this cross-fertilization of functions maintains knowledge creation and diffusion, and facilitates entrepreneurial experimentation through multi-stakeholder engagement as scientific breakthroughs diffuse into AI applications:

> There's a sure amount of academics who have bled into the entrepreneurial realm in the last couple of years … [and] have been able to grow the academic work into industry.
>
> (INT18)

Notably, the AI 'ecosystem' revolves around Montreal's scientific community, with universities and PRLs strengthening as *anchors* that sustain the core of current developments. Knowledge creation and diffusion have intensified significantly in this phase, and with 'demand for talent very high right now' (INT2), universities and PRLs are central to maintaining the talent pipeline that 'feeds' the TIS. This, in turn, serves to attract other resources:

> Because the [AI] space is moving so fast, you need a strong access to research to be a leading company.
>
> (INT14)

> Montreal is on its way to becoming a world-renowned AI cluster because you've got the researchers here which attracts more researchers, which attracts more companies, which attracts more VCs, and it just compounds.
>
> (INT27)

Moreover, in 2018 Bengio (with Hinton and LeCun) was awarded the Turing Award, known as the Nobel Prize of computing, for laying the foundations for modern AI, *valorizing* their major contribution to the field. Such resounding scientific success 'brought talent back to Canada' (INT15), with Montreal experiencing a significant inflow of international talent. With more than 11,000 students now enrolled in AI and data-related programmes (Montréal International, 2019), Montreal has the highest concentration of deep learning researchers in the world. Thus, 'there's a critical mass of talent' (INT2) that is increasingly *anchored* by universities and research institutes from outside the region.

The agglomeration of talent and actors has also seen an intensification of knowledge diffusion through networks: 'I don't think there's an evening where there's not a forum or an event around AI, machine learning' (INT12). Fostering a collaborative community of researchers and start-ups, the region has developed a

'meet-up culture [that] is very alive' (INT6) in diffusing knowledge within the TIS. The impetus for collaboration has also given rise to formal networks, such as the Institute for Data Valorization (IVADO). Bringing together more than 1000 scientists and industry professionals, IVADO provides a bridge between academic knowledge and business needs. It also spearheads a major project (Data Serving Canadians) funded by the federal government and led by University of Montreal.

Indeed, many of the advances achieved in the formative stage were made possible through the support of the *state*, which became an 'aggressive actor trying as much as possible to drive innovation' (INT7) in AI. As an interviewee emphasized, the region benefits from:

> a government that's open to innovation like no other. Montreal has that aspect going for it perhaps more than other cities. You've got a government that's actively trying to foster the proliferation of an innovation culture.
>
> (INT7)

State-led support for AI development is delivered through complementary multilevel initiatives across federal and provincial levels, which collectively contribute to knowledge creation and diffusion, market formation, entrepreneurial experimentation, and legitimation, and which influence the direction of search. While in the pre-formative phase it was the federal government that primarily supported AI development by funding basic research, in the formative phase where AI emerged as a potential regional economic opportunity, the provincial government started to complement federal-level initiatives. Key initiatives at the federal level include the Canada First Research Excellence Fund (CFREF)[3] (C$ 93.5 million awarded to University of Montreal\rpar and the CIFAR-led Pan-Canadian Artificial Intelligence Strategy, with C $40 million allocated to Québec aiming to boost AI research and innovation. Additionally, the Government of Québec allocated C$100 million for the creation of an AI cluster in the region. Such funding is critical to supporting continued scientific research:

> You've got funding coming in for the next five–ten years that's going to support your students, get your research projects going, and that's really important because the biggest gap in research is that lack of funding.
>
> (INT8)

A major programme is also the Innovation Superclusters Initiative, a C$ 950 million federal-level investment aimed at creating innovation-led regional growth engines. In 2018, Montreal was awarded C$230 million from the federal government for SCALE.AI, one of five funded and the only AI-focused supercluster. The Government of Québec later awarded and additional C$23.4 million to the initiative. The funding influences the direction of search by engaging academia and private actors to explore AI applications for supply chains.

There are also introduced a number of programmes aimed at fostering entrepreneurial experimentation. These include a tax credit for scientific research and experimental development of 15% refundable from the federal government and 14% from the Québec government, a provincial refundable tax credit for e-business development covering up to 30% of salaries per year, and a 'tax holiday' exempting foreign researchers and experts from income tax for five years. These incentives create an attractive environment for global players who opened AI research labs and AI start-ups by greatly reducing their operational costs. They also help attract global talent, thus fuelling expansion in the formative phase. These are complemented by AI-targeted investments by the federal and provincial government, which funded AI accelerators (e.g., NEXT.AI, Creative Destruction Lab – CDL) to support the formation and growth of AI start-ups. The *state* also used immigration policy strategically as a vehicle for resource mobilization, making it easy for companies to employ international talent:

> If I want to hire someone from, let's say, Spain or Egypt or anywhere in the world, if they have a PhD and are good in AI, and I can prove it, I can have them here in three weeks.
>
> (INT17)

Such complementary multilevel *state*-led efforts serve to legitimize the ecosystem and cement AI as a new regional path, and highlight the particularly active role of the provincial government which has a rich tradition of using science and technology policy initiatives to achieve socio-economic objectives (Salazar & Holbrook, 2007): 'both provincial and federal governments are working together on backing this AI strategy [which] shows how strong the ecosystem is here in Montreal, which attracts a lot of investors [and] big firms' (INT24). Importantly, this coagulation of academia, industry and government actors that underpins the formative phase has led to a more strategic approach to system-building. Collaboration among this triad of *trailblazers*, *anchors* and *the state* generated a virtuous cycle that fuels system-building and cements AI as a new regional path:

> The unique characteristic of Montreal is the coupling between government, industry and academia. We've got very good universities that produce the right calibre of AI talent. … That attracts international talent and becomes a good source of recruitment for local companies. The government has made it very attractive for companies to position themselves here in Montreal. … Then the corporations, by virtue of the other two factors, have been attracted to Montreal, and that forms an ecosystem that just fuels itself.
>
> (INT21)

Finally, highlighted as the 'glue' that holds the ecosystem together, Montreal's collaborative culture and shared vision put forward by system-builders are driving the

further development of the TIS, creating collective expectations of growth that strengthen legitimacy and influence the direction of search:

> [There is] a common interest to see Montreal succeed as a whole. Everybody's got their own agendas … but there's a general willingness to see the city flourish.
>
> (INT21)

> A vision that I have put forward is that of nurturing an ecosystem generating AI global giants in Canada on the scale of Google or Facebook, and MILA has as part of its mission to favour the development of AI start-ups thanks to our expertise in deep learning and ability to train more talent.
>
> (INT29)

Importantly, the vision articulated and shared by regional actors demonstrates how expectations about the future can drive the growth of regional industrial paths, an aspect that has hitherto been overlooked (Hassink et al., 2019). It contributes to further mobilization of resources and strengthens networks between system-builders to support further experimentation. As summed up by an interviewee, the success of entrepreneurial experimentation can propel the TIS to the next level: 'I think that Montreal will become the epicentre of AI development period. … If we nurture it, we will become the Silicon Valley of AI' (INT1). However, as the last section highlights, this vision remains reliant, at least in part, on the success of legitimation efforts to increase the societal acceptance of AI.

AI and institutional alignment: legitimizing AI as an emerging challenge

The interviews highlighted that an emerging challenge to the further development and diffusion of AI is its wider social acceptance and use, with AI applications being met with concern, suspicion, or even resistance globally. This stems from its disruptive nature, as AI applications can profoundly affect labour markets worldwide and exacerbate socio-economic inequalities, while raising privacy concerns and fears of harmful deployment. Indeed, while some believe that AI will usher in a prosperous future for all, others highlight important ethical concerns and potentially devastating socio-economic consequences, including job losses, the weaponization and malicious use of AI, privacy violation, risks of algorithmic bias and unintended consequences (Butcher & Beridze, 2019). Given that 'the higher the reconfiguration capacity of a technology is, the more institutional work is required to achieve a diffusion' (Fuenfschilling & Truffer, 2016, p. 302), substantial institutional agency will be required to alleviate existing concerns and to foster alignment between AI and the institutional context to achieve wider diffusion. The main challenge is not infrastructural, 'because AI is an addendum to existing software systems so it can be embedded and deployed right away' (INT31), but the wider societal acceptance of AI.

Here, the region is already responding through early legitimation efforts and an intensification of institutional work, with actors coalescing to respond to and address these emerging legitimation challenges: 'Québec made the choice of saying fine, we do AI, but it has to be done in an ethical and responsible way' (INT21). A number of initiatives aiming to legitimize AI on a wider scale have seen local and regional actors jointly involved in political work and advocacy efforts through new interest groups and intermediaries that are lobbying for the ethical and socially responsible development of AI. Notably, these include the Montréal Declaration for a Responsible Development of Artificial Intelligence launched by the University of Montreal in 2017 in collaboration with the Government of Québec. The result of consultation with citizens, experts and AI stakeholders, this provides a set of ethical guidelines and principles for AI development (Université de Montréal, 2017), with signatories committing to adhere to these principles.

Additionally, the Montreal AI Ethics Institute (MAIEI) was founded in 2018 as a bottom-up initiative to build public understanding and promote a wider understanding of the societal impacts of AI. As a normative network including industry, academia and government representatives, it places civic engagement at its heart. As an interviewee explained, 'for change to happen … you need top-down institutional frameworks and policies' (INT31). MAEI positions itself as a public policy entrepreneur, generating dialogue around issues such as social inclusion, the future of work, ethics, and privacy to support the development of frameworks for the ethical and responsible application of AI.

Such institutional work is also supported by the *state* through the funding of normative networks, with the federal and provincial government pledging C$15 million for the creation of a Montreal-based international centre of expertise for the advancement of AI. As a normative network of experts and AI stakeholders, it will leverage Montreal's expertise in AI and contribute to developing standards and practices for ethical and responsible AI development. This is in addition to another initiative led by the Government of Québec involving the creation of a Montreal-based international observatory on the societal impacts of AI and digital technologies (OIISIAN), which aims to maximize the benefits of AI and mitigate the potential negative effects.

The proliferation of such legitimation initiatives aimed at fostering institutional alignment highlights the challenges ahead, which are likely to have a significant impact on the further development of the TIS. Not only are these initiatives sending a signal to AI companies with regard to what is socially desirable and acceptable in term of AI applications, but they can also influence the demand for AI products and lobby for change where new applications deviate from normative frameworks and principles. Importantly, these legitimation activities can impact the evolution and outcome of other system-building functions such as entrepreneurial experimentation, with demand for stricter AI regulations potentially affecting the commercialization of AI

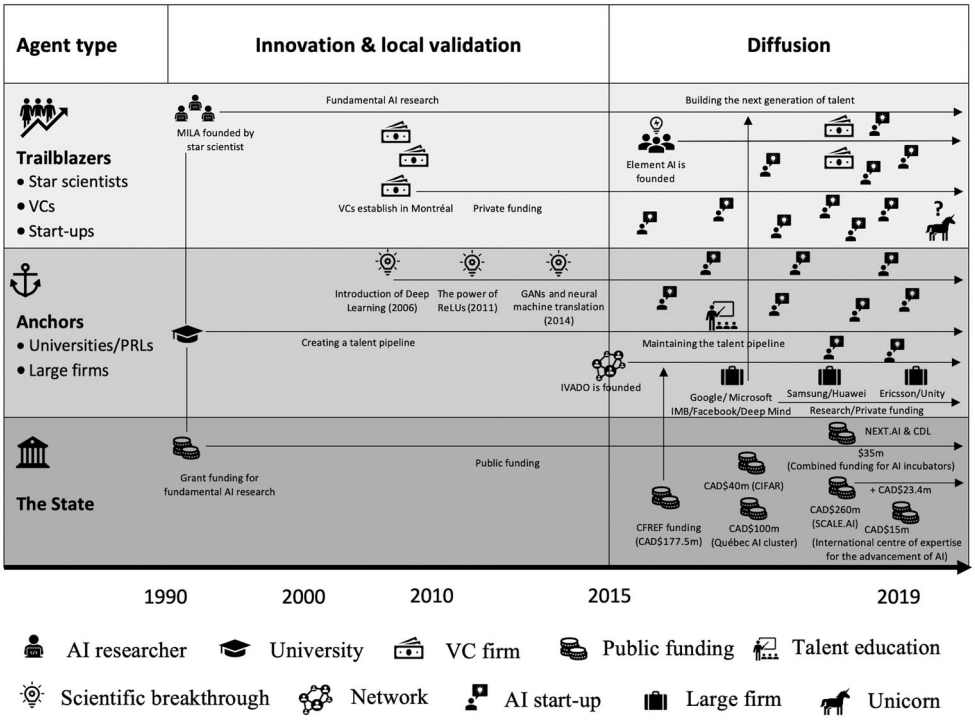

Figure 3. Development of the artificial intelligence (AI) technological innovation system (TIS) in Montreal, Canada.

products and services, and can influence the direction of search. Therefore, whether the ecosystem 'shifts gear' again and progresses to the next developmental phase is as much a question of legitimation success as it is a question of entrepreneurial success.

DISCUSSION

The findings highlight the role of *trailblazers*, *anchors* and *the state* in the development and legitimation of AI throughout the pre-formative and formative system-building phases. The analysis reveals how the agency of these different actor groups evolved from distributed and uncoordinated to more strategic, with system-building efforts intensifying in the formative phase, as mapped in Table 3. Figure 3 provides a temporal perspective based on the legitimation phases introduced by Binz et al. (2016a), highlighting key landmarks and developments that contributed to TIS formation and regional path creation.

As Figure 3 illustrates, it took more than two decades for the system to transition from the pre-formative to the formative phase and AI to emerge as a new regional path. The long pre-formative phase was dominated by knowledge creation through fundamental research facilitated by the uncoordinated agency of a small number of actors (*trailblazer* star scientists and VCs, research funding agencies supported by *the state*). Breakthroughs in this phase propelled the system onto the next, more intensive system-building phase of technological diffusion.

While in the pre-formative phase resources were created endogenously through the interplay of a small number of actors, the crystallization and growth of the TIS in the formative phase is driven by an intensification of system-building activities through a combination of developing, distributed and deliberate agency (Musiolik et al., 2018) and the anchoring of exogenous resources, from international investment to research and entrepreneurial talent. This ongoing formative phase is characterized by rapid expansion and agglomeration through new firm formation and entry of new actors, network formation and increased legitimation efforts. Notably, it has seen a proliferation of AI start-up activity and an intensification of system-building activities. The different actor groups have coalesced in a much more coordinated and strategic way to cement AI as a new regional path, with knowledge diffusion, market formation, entrepreneurial experimentation, resource mobilization, and legitimation efforts dominating this phase. With regard to the latter, particularly notable are the system-building efforts by early VCs and the emblematic success of regionally embedded star scientists. These served to build trust, legitimizing the ecosystem and attracting other actors to the region. The result is in an 'ecosystem' driven by collaborative multi-actor agency with academia, government and industry working in tandem.

Moreover, progress is driven by a shared vision of regional growth and expectations that the ecosystem will be able to generate 'AI unicorns' (AI start-ups valued at over US$1 billion): 'We will see several AI unicorns coming out of Montreal; it's a matter of time' (INT9). This would not only further contribute to legitimation but would release important resources back into the ecosystem to fuel the next phase of growth: 'You need a couple of sales, so you can exit and invest back in the

ecosystem' (INT20).[4] This vision and belief in future commercial success provide a strong influence on the direction of search. However, substantial and sustained collective institutional agency will be required if AI is going to progress to a general validation stage. This has already seen institutional work intensify, as illustrated by the recent emergence of interest groups and intermediaries in Montreal that aim to contribute to and promote the ethical and socially responsible development and use of AI.

CONCLUSIONS

This paper has examined the emergence of AI in Montreal as a new regional path through the lens of system-building, providing an in-depth *multi-agency* and *multi-scalar* perspective on regional path development (Hassink et al., 2019). The findings demonstrate the value of the TIS framework used for debates in EEG. A significant contribution to the advancement of a multi-actor approach to path development has been made through the detailed analysis of the changing role of various actors from university, government, and business institutional spheres in the cultivation of the AI ecosystem. The increasingly coordinated nature of this work as the TIS has moved into the formative phase of more deliberate system-building and legitimation activities reinforces the importance of interactive forms of system-level or institutional agency as an integral part of the regional path development process (Grillitsch & Sotarauta, 2019; Isaksen et al., 2019). The system-building work discussed here however extends this perspective by considering how the emergence of new industrial paths based on analytical knowledge bases will be accompanied by processes of new institutional formation within a region. This shows that the TIS functions featured in the conceptual framework (knowledge creation/diffusion, resource mobilization, market formation, influence on direction of search, entrepreneurial experimentation, and legitimation) need to be recognized as key processes within new regional path creation.

The findings also highlight the need to recognize path development as a complex process with multiple distinct stages (Baumgartinger-Seiringer et al., 2020). In particular, the case study has demonstrated that a new path can grow in an analytical knowledge base domain from assets built up during a pre-formative phase that precedes the emergence of a significant local industry. Here, the role of government and university-based actors was central in funding and performing more exploratory forms of fundamental scientific research that was disconnected from short-term market pressures (Vallance, 2016). The purpose behind these activities shows that, despite a degree of serendipity involved, the emergence of AI as a regional path in Montreal was not the result of 'historical accident'. This also represents an alternative pre-formative phase to that in which knowledge, technologies, and other institutional assets are inherited from existing local industries as a precursor to new path creation through regional branching (Martin, 2010). Despite new scientific knowledge relating to AI being the catalyst in this case, path creation did not occur through a simple linear process of research commercialization. Instead, wider system-building and legitimation activities, requiring the continued involvement and collaboration of multiple actors (including *anchor* universities and the *state*), have been an essential dynamic as the TIS has moved into the formative phase.

The paper also points towards avenues for future research that build on its conclusions about path development in analytical knowledge base industries. Its limitations as a single case means that there would be value in comparative studies of the scientific and commercial development of AI and/or related industries in other regions within North America or internationally. In particular, it will be important to see if path-creation processes follow similar patterns in contexts without the same combination of enabling factors identified in Montreal. The nature of AI as an emerging general-purpose technology also means that there is a need to understand how these different regional paths are connected together on a potentially global scale. Montreal has played a distinctive part in the modern wave of AI, but this has clearly not taken place within a closed territorial system. Instead, endogenous development processes have combined with the anchoring of exogenous resources from such sources as the federal government, major U.S. technology corporations, and international talent attracted by local universities. The TIS literature that has framed this analysis does not (in comparison with regional innovation systems approaches in economic geography) represent an inherently spatial perspective. An awareness of the varying local and non-local spatiality of the different processes involved in the emergence of a TIS may, however, be one way in which economic geographers can continue to develop a stronger multi-scalar understanding of path development.

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DISCLOSURE STATEMENT

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NOTES

1. In Canada, the federal government is responsible for the science, technology and innovation policy. Through a single nationwide innovation policy, it promotes initiatives that fund basic research. Provincial governments largely complement federal policies and programmes and deliver innovation policy. See Salazar and Holbrook (2007) for a discussion of Canadian science, technology and innovation policy.
2. CIFAR is a Canadian-based global research organization that supports leading-edge research with the potential for global impact. Since its inception in 1982, the organization has been supporting long-term interdisciplinary collaboration that yielded breakthroughs in many disciplines. CIFAR has played a major part in the deep-learning revolution by funding AI research through programmes such as Learning in Machines & Brains, which continues to this day.
3. CFREF is a federal tri-agency initiative that supports Canada's postsecondary institutions excel globally in research areas that create long-term economic advantages for Canada.
4. On 30 November 2020, Element AI announced its acquisition by American company ServiceNow, which will use this as a platform to establish an AI innovation Hub in Canada. While set to release significant capital, the exit also raises important questions for the future of Montreal's AI ecosystem, which will lose a key anchor firm.

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