Challenges of Coordination: Automotive Innovation in the Ontario Supply Chain in Comparative Context

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Dans le sud de l'Ontario, où se trouve un pôle industriel automobile, des politiques permettent de soutenir de nombreux projets de recherche portant sur l'application de technologies habilitantes. Toutefois, ces projets ne répondent aux besoins que d'un faible pourcentage d'entreprises, les fournisseurs très novateurs, et ne touchent pas la base manufacturière traditionnelle. La situation est pourtant très différente dans d'autres pôles industriels automobiles, comme Detroit, au Michigan, les West Midlands, au Royaume-Uni, et le Bade-Wurtemberg, en Allemagne, où les projets de recherche appliquée concernent l'ensemble des entreprises de la chaîne d'approvisionnement. Dans cet article, nous avançons que l'Ontario doit tirer d'importantes leçons de ces nouvelles formes de coordination industrielle afin d'empêcher l'érosion des capacités d'innovation des entreprises de sa base manufacturière automobile traditionnelle.

Mots clés : pôles industriels automobiles, recherche appliquée, coordination industrielle, politiques en matière d'automobiles

Policies for the southern Ontario automotive cluster support multiple collaborative research projects designed for the application of enabling technologies. However, these initiatives cater to a small percentage of highly innovative automotive suppliers and exclude much of the traditional manufacturing base. This stands in contrast to automotive clusters in Detroit, MI; the West Midlands, United Kingdom; and Baden-Württemberg, Germany, where applied research collaborations target the entire supply chain. With respect to policy implications, we argue that new forms of industrial coordination emerging in competitor regions may offer critical policy lessons for Ontario on how to stem the erosion of innovation capabilities in its automotive supply base.

Keywords: automotive clusters, applied research, industrial coordination, automotive policy

Introduction

The southern Ontario automotive cluster faces a complex set of innovation challenges, with the majority of automotive research and development (R&D) performed abroad by resident original equipment manufacturers (OEMs) and intensified competition for investment from other North American jurisdictions. To improve the sector's competitiveness, policies adopted in the wake of the 2008–2009 financial and automotive crisis directed increased support to more applied research through both industry-specific initiatives, such as the Automotive Innovation Fund, and collaborative research efforts into enabling technologies to promote more sustainable production operations. Simultaneously, there have been several private sector–led initiatives to reinvigorate segments of the automotive supply chain.

This article examines the impact of several new policy measures and collaborative initiatives on the value-added activities of companies in the automotive supply chain and related sectors. These developments are situated in a comparative context by reviewing similar policy and industry developments in comparable regions in North America and Europe, drawn from a literature review. These policy shifts in Ontario and other jurisdictions are occurring in a context in which intensified international competition and cost pressures have combined with stricter corporate average fuel economy environmental regulations and consumer safety standards to drive innovation further down the automotive supply chain. The range of technologies that are important to success in the industry has expanded—from electronics to digital platforms, new fuel and power technologies,

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and lightweight materials. The need for more systemic innovations has led to a process of increasingly open innovation (Chesbrough 2003), shifting the locus of innovation from within a single firm, the OEM, to a wider range of firms along the supply chain, research institutes, and end users (Köhler et al. 2012). The critical challenge concerns the ability of firms located at various stages along the automotive supply chain in Ontario to adapt to this shifting locus of innovation.

This article reports on an in-depth study of several collaborative initiatives undertaken to augment the innovative capacity of firms in the southern Ontario automotive supply chain. The study's results suggest that a key objective of these initiatives has been to lower the cost of applied research and reduce the time and risk associated with the transition from designs to functional prototypes for firms located at various stages of the production process along the supply chain. The expectation is that funding the later stages of product development and technology adoption will reduce the gap between the research and commercialization processes.[1] As a lens into the goals of these efforts, we focus on the conceptual framework of technology readiness levels (TRLs), which originated in the space sector but is increasingly being adopted by policy-makers in both the United States and Canada to allocate funds to projects in the later stages of the development process (TRLs 3–7) across a growing spectrum of industry sectors.[2] Developed by the National Aeronautic and Space Administration in the 1970s and widely disseminated throughout the space sector, the TRL approach is used to provide a common framework for sharing reliable measures of a new technology's degree of maturity among technology researchers and program executives working on technology development initiatives. Definitions for the seven TRLs currently in use by the federal government are provided in the Appendix (Table A).

Concurrent with the growing relevance of open innovation, studies of national policies document a convergence toward a renewed form of industrial policy characterized by (a) growing coordination between initiatives, (b) longer term funding horizons, and (c) reliance on public–private partnership arrangements (O'Sullivan et al. 2013). Despite a growing literature on national policy styles, systematic studies of the impact of these differences at the subnational level are lacking, which becomes relevant when one observes that not all automotive regions have similarly adjusted to the emergence of more complex forms of product and process development. In addition, automotive regions have also followed varied growth trajectories, with some becoming highly innovative or design-intensive automotive development and production regions, as well as developing product innovations in market niches peripheral to the automotive industry, whereas others have remained in the low value-added segments of the industry (Plum and Hassink 2013).

To situate Ontario in a comparative context for these changes occurring in the industry, we review recent developments in the West Midlands, United Kingdom; Detroit, Michigan; and Baden-Württemberg, Germany, all of which have developed a substantial basis of small- and medium-sized engineering and design companies. In contrast to the experience of these competitor regions, in Ontario the majority of the supply base remains focused on incremental process improvements, and new manufacturing investment by OEMs has primarily been located south of the border or in Mexico (Rutherford and Holmes 2014; see also Fitzgibbon et al. 2004). Ontario is not unique in this respect; some regions in leading manufacturing countries, including Germany's Southwest Saxony, are struggling to stay ahead of their competitors (Plum and Hassink 2013).

The critical issue is how effective these policy measures have been in overcoming the barriers to innovation in the southern Ontario automotive supply chain. Unlike past OEM-oriented initiatives, recent policy efforts aim to include more regional small- and medium-sized enterprises (SMEs) in applied research networks. Our analysis of the impact of these policy initiatives draws on 25 interviews conducted with key innovation support intermediaries in a federal research laboratory, a major research university, community colleges, and a business-led research network.[3] Interviewees were asked to quantify the distribution of their collaborative research projects across the range of the TRL scale and identify the main beneficiaries of the services they provided. Our findings suggest that these initiatives are often geared toward the needs of a relatively small number of highly innovative automotive parts SMEs and do not extend to a broad enough range of firms to encourage technology upgrades across the traditional manufacturing base. Consequently, recent investments to support applied research might not prove sufficient to enhance the innovative capabilities of southern Ontario's automotive supply chain. With respect to policy implications, we argue that policy-makers need to pay closer attention to how new forms of industrial coordination emerging in competitor regions may offer critical lessons for policy-makers on how to stem the erosion of innovation capabilities in the automotive supply base. Thus, the article both builds on and adds to the existing literature on automotive policy across competitor regions.

Recent Trends in Innovation along the Automotive Supply Chain

Scholars have long predicted a third revolution in the automotive industry, which is gradually unfolding in

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the form of current changes in business strategies and industrial models (Helper 2011; Herrigel 2010; Jürgens and Meißner 2005). The knowledge bases on which automotive manufacturing and innovation rely are also shifting across automotive regions (Plum and Hassink 2013). The automotive industry has traditionally drawn on a synthetic (engineering-based) knowledge base, but growing evidence suggests that the production of automobiles in some clusters relies not only on synthetic but also on analytical (science-based) or symbolic (design-intensive) knowledge inputs (Asheim and Coenen 2005). The concept of "combinatorial knowledge" introduced by Strambach and Dieterich (2011) suggests a growing tendency on the part of automotive companies to integrate formerly discrete knowledge bases:

> The creation of "combinatorial knowledge" … gains a more prominent position for firms in innovation development. In contrast to "cumulative knowledge," that is knowledge which builds on or is directly dependent on already existing stocks of knowledge, "combinatorial knowledge" comes into existence by the unification of originally separate knowledge bases. It is characterized by bringing together formerly separate knowledge bases spanning over distinct organizational, sectoral and territorial contexts. (7)

Supply chains in many automotive jurisdictions have not fully adapted to these changes or remain locked into a trajectory of incremental process innovation. Research indicates that companies across the board, and especially SMEs, encounter significant barriers in bridging the gap between research on enabling technologies and their diffusion into company operations, which encompasses TRLs 3–7. This suggests that changes in modes of knowledge creation need to be accompanied by economic and institutional restructuring to aid firms in older industrial regions in the adoption of new approaches to innovation (Strambach 2001).

The inability to redeploy resources into new sectors and activities is attributed to network failures "where formal and informal institutions fail to align with company strategies or foster the growth of skill and technical capacity" (Schrank and Whitford 2011, 162) or where there is opportunism and a lack of trust and loyalty between OEMs and their suppliers. Scholars suggest that government policy can facilitate the formation of supportive institutions—including technology intermediaries—that improve innovative capacity and support confidence-building measures. Specifically, intermediaries can facilitate a German-like model of applied research cooperation between universities and industries and also support technology transfer (in the manner of the Steinbeis Foundation and Fraunhofer Institutes) to move technology from TRL 3 to TRL 7 (Rutherford and Holmes 2008).

Recent research on policy developments in competitor jurisdictions, including the United States, United Kingdom, and Canada, has found some evidence of increased efforts by public officials, private sector actors, and intermediary associations to adopt more cooperative arrangements along the lines of the German model (O'Sullivan et al. 2013; Wessner 2012). The goal of these efforts is to promote linkages that the existing institutional arrangements have not supported, reflecting the need for new forms of collaborative or networked governance to promote more effective technology development and diffusion across the supply chain (Kraemer 2006). Policies have evolved from a traditional approach based on product market intervention (subsidies, state ownership, tariff protection) toward a coordinated set of measures in the form of non–sector-specific funding for activities such as R&D, environment restoration, and labour market programs and to create networks, develop institutions, and align strategic priorities.[4]

Despite some evidence of this trend toward greater policy convergence at the national level, networked governance arrangements continue to differ across key automotive jurisdictions at the regional level. In the case of revitalized automotive clusters such as Detroit, Michigan; the West Midlands, United Kingdom; and Baden-Württemberg, Germany, efforts by technology intermediaries designed to promote greater innovation along the automotive supply chain are not targeted solely at basic research or university–industry applied research but aim to facilitate the adoption and diffusion of technology among a broad cross-section of SMEs. Our research suggests that this is not the case for Ontario, where the focus remains on applied research initiatives that do not include the majority of SMEs in the automotive supply chain, or for Southwest Saxony in Germany, where incremental improvements remain the central focus.

Hence, there continues to be substantial variation in the way in which coordination mechanisms are adopted at the regional levels that cannot be explained entirely by the broader trends observed at the national level. We contend that understanding the relative success or failure of these emergent forms of collaboration requires greater attention to regional policy variations and the manner in which both firms and public officials succeed in using new policy measures to promote greater innovation in their respective jurisdictions and integrate their local production activities into global supply chains. The following section provides an overview and comparison of automotive-related policies on both the national and the subnational levels in Detroit, the West Midlands, Baden-Württemberg, and Southwest Saxony.

Comparing Automotive Policies in Industrial Regions

Although the focus varies across the regions, the emphasis in policy strategies has often been on the global positioning of the regions as centres of excellence in design and innovation in global automotive and technology markets. In the United States and the United Kingdom, regional-level goals have been aligned with national industrial policy to support objectives such as low carbon emissions and intelligent traffic systems.[5] Initiatives often function under the label of assistance for advanced manufacturing but help build regional automotive knowledge by advancing generic technologies that can be used to revitalize the sector. Even Germany, considered a leader in the manufacturing segment, is adopting strategies to revamp production.[6] Despite the multitude of fertile industrial ecosystems, scholars have identified a gap between disciplinary research in the university and interdisciplinary research in the extra-university sector (Edler and Kuhlmann 2008). In contrast to these competitor jurisdictions, Canada did not adopt a formal strategy until 2015. Despite the creation of several standalone programs, there has not been an integrated strategy guiding how funds are allocated, with private actors often driving the agenda.

Comparative Regional Analysis: Germany, the United States, the United Kingdom, and Canada

Regions in which automotive clusters have been revitalized, such as the West Midlands, Detroit, and Baden-Württemberg, are characterized by a strong SME base and coordination initiatives that have contributed to their ability to utilize innovation resources.[7] Other regional initiatives, including those in southern Ontario, direct funding to applied research but do not extend their services to SMEs that are concentrated in the low value-added segments of the industry.

In the case of the West Midlands, suppliers were initially smaller and more interested in survival than in R&D. In the early 2000s, however, access to innovation resources was enhanced through publicly assisted automotive-specific programs created to encourage innovation by disseminating best practice, transferring technology, raising awareness of technology trends, and identifying sector-specific business needs (Lawton-Smith et al. 2001). Regional and local government support was essential to the formation of the Society of Motor Manufacturers and Traders (SMMT) Industry Forum, where senior purchasing directors from vehicle manufacturers, along with counterparts from SMEs, met to develop and implement common approaches and shop floor processes (MacNeill and Bailey 2010). More recently, the government has introduced a package of supply and demand initiatives, among which is the Automotive Composites Research Centre (ACRC) at the University of Warwick, which is part of the HVM Catapult Program to promote cross-cutting relationships between previously isolated activities (Waddington 2013). The HVM Catapult Program is part of the UK HVM Strategy targeted at 22 national competences in both large and SME firms across multiple sectors. In particular, the ACRC focuses on the development of carbon fibre–reinforced composite manufacturing technologies for high-volume automotive applications. The goal is to provide industrial partners with state-of-the-art, industrial-scale composite processing equipment to carry out process development and demonstrations at TRL 3–7.

The Detroit case also demonstrates that the innovative competencies of smaller and independent businesses are essential to achieving a more flexible structure of engineering and production. Sturgeon et al. (2009) note that the increased involvement of suppliers in vehicle design—as a result of the importance of relational linkages in the automotive industry—has led to a spatial concentration of supplier design and engineering facilities. This spatial concentration has been facilitated by Detroit's reputation as one of the most developed automotive regions, with a specialized labour force and several institutions that support automotive engineering. Although government intervention in enabling this outcome was not as extensive as in the UK case, Helper (2011) found that initiatives such as the Michigan Manufacturing Technology Center contributed to the propensity of automotive firms to compete on the basis of quality rather than cost. Local government officials played a central role in this process through efforts to leverage the strength of Oakland County's high-tech companies into a national marketing strategy designed to attract new talent and development while helping to grow existing firms, the result of which was Automation Alley. The organization's mandate was to provide technology-oriented companies with linkages to regional resources and international export markets to accelerate the commercialization and transfer to market of new high-tech products and services (Muro and Katz 2011).[8] Despite the loss of some final vehicle assembly activity, the vitality of the cluster has been reinforced, with suppliers increasingly engaged in new vehicle development programs.

More recently, Detroit development officials have adopted the express goal of helping the region diversify by promoting a cluster of advanced battery technology encompassing the entire supply chain. There has been ongoing recruitment of battery pack manufacturers and vehicle electrification programs, along with the development of a comprehensive strategy, including investments in R&D, generous tax incentives, extensive training programs, and public–private partnerships between universities, industry, government agencies, and the US Army (Galvin, Goracinova, and Wolfe 2015; Wessner 2012).

In contrast, the region of Baden-Württemberg provides a model of a more institutionalized regional innovation

Table 1: Policy Features of Renewed Automotive Regions (Goals and Types of Initiatives)

Type of Initiative	Goal
Strategy	Global positioning of the regions as centers of excellence in design and innovation in global automotive markets (or, more broadly, technology markets). Aligned with national-level strategies (low carbon and intelligent traffic systems)
Collaborative initiative leader	Different mixtures of public, public–private, and privately led initiatives
Instrument	Move toward financing of applied research; helping firms cross the valley of death (higher TRLs)
Goals	Supply chain focus (particularly on SMEs), not just front-end R&D or assembly (i.e., also production, niche manufacturing, high-value engineering); push technology down the supply chain, not simply transfer innovations to high-tech start-ups.

Note: TRLs = technology readiness levels; SMEs = small- and medium-sized enterprises; R&D = research and development.

system, although one that is better suited for incremental, rather than disruptive, technological change (Heidenreich and Krauss 2004). Unlike the case of the UK and the US automotive regions, it has strongly and publicly supported innovation centres that both generate knowledge and encourage its exploitation, playing a boundary-spanning role that strengthens the regional innovation system. This function is performed by intermediary technology transfer agencies, which create linkages between the research results generated in universities and public research laboratories and their commercialization in domestic companies.[9] Nonetheless, some scholars have expressed concern that Baden-Württemberg might not be able to catch up to leading automotive technology clusters because of its continued focus on conventional vehicle technology. In fact, they argue that technology development is confined to a few lighthouse companies, and the limited cooperation with SMEs might be a threat to regional success (Zanker et al. 2015).

In response to these concerns, policy efforts at the national and subnational levels have introduced projects to advance new technologies, such as electric mobility, along the value chain. These projects have included the launch of a federal electric vehicle mobility strategy designed to support the emerging technology shift toward electric vehicles and pave the way for their production through the targeted integration of SMEs into the innovation process. The federal government has also implemented initiatives such as the Southwest Cluster to capitalize on Baden-Württemberg's established SME networks, educational infrastructure, and large manufacturers (Zanker et al. 2015). Similarly, Baden-Württemberg has used European Union funds to provide targeted support to statewide innovation platforms, which led to the launch of competition for strengthening regional clusters in Baden-Württemberg. Winning clusters belong to 25 technology areas identified through the cluster dialogue. Under the automotive technology heading, Automotive-bw was established in 2010 to facilitate exchange among automotive industry stakeholders within the state and throughout the entire value chain, drawing on the expertise of preexisting networks such as Automotive Engineering Network, which was founded in 2005 as a supplier network connecting more than 80 companies and institutions in the region (Strambach and Dieterich 2011). Table 1 summarizes some of the key features found in regions that have adopted measures to renew their automotive sector.

In the case of Southwest Saxony, which stands in contrast to the ones discussed earlier, linkages between universities or polytechnics and SMEs have been notably weaker. SMEs rarely have access to global technology pipelines and are often dependent on the knowledge transfer connections of OEMs. Scholars have questioned whether the automotive cluster in Southwest Saxony should pursue a high-tech strategy or follow a different path whereby automotive suppliers diversify into other industries (Plum and Hassink 2013). This raises the question of how a technology intermediary strategy or infrastructure can be crafted with different goals in mind, which reinforces the significance of regional characteristics for emerging forms of coordination. The variation in the German case between Baden-Württemberg and Southwest Saxony illustrates the increasing difference between coordination mechanisms that exist at the regional level within jurisdictions operating with the same national-level institutions and policy frameworks.

Southern Ontario Automotive Cluster

The onset of the economic crisis in 2008–2009 directed greater attention to the need for applied research to help companies upgrade their technological capabilities in the southern Ontario automotive cluster. In contrast to the cases discussed earlier, initiatives adopted in Ontario have primarily targeted the needs of large OEMs and, more recently, a smaller segment of high-tech firms, which encompass only 10 percent of the automotive supply chain (Rutherford and Holmes 2008, 2014). The new initiatives described in this article are not all automotive specific but are intended to support the needs of advanced manufacturing SMEs more generally. However, the individual policy measures have not been adopted as part of a focused, consistent strategy aimed at revitalizing the automotive supply chain or manufacturing more broadly, as is the case with the competitor jurisdictions discussed earlier.

Growing efforts in the United States and Europe to transition away from the internal combustion engine paradigm pose a particular challenge for the Ontario automotive cluster. In contrast to the more ambitious technology strategies adopted in these jurisdictions, recent studies find that policy measures introduced in Ontario have maintained a consistent focus on incremental process improvements targeting the majority of Ontario automotive SMEs (Rutherford and Holmes 2014). Despite this more limited policy focus, Ontario firms have demonstrated some ability to innovate, but they often lack the resources to undertake efficiency improvements and are forced to rely mainly on labour cost reductions to deal with lower order volumes (Bathelt, Munro, and Spigel 2013, 1121). Another reason for the Ontario automotive cluster's lower level of innovation capabilities is its historical status as an entrepôt cluster with most knowledge acquired through market and global sources rather than a regionally embedded one with strong R&D capabilities in which the principal source of innovation is the local knowledge–science base (Wolfe and Gertler 2004).[10]

The lack of a clearly articulated automotive strategy for southern Ontario has been attributed to obstacles in the coordination between the federal and provincial governments stemming from political distrust, bureaucratic silos, and the long lead time needed to coordinate across multiple ministries and levels of government in the federal system (Yates 2015). This has resulted in problems with program implementation and their subsequent impact, given that the individual initiatives are not part of a broader strategy but are stand-alone programs with limited reach and funding.

Canadian Manufacturing Policy and the Southern Ontario Automotive Cluster

The current challenge for policy-makers concerned with improving the innovation capabilities of the southern Ontario automotive cluster involves the need to move away from the traditional reliance on university-based research toward greater support for funding applied research and an enhanced role for innovation intermediaries. Past federal funding initiatives, such as Auto21, a national Network of Centres of Excellence project, which facilitated university–industry collaboration, and Automotive Partnership Canada, established as part of the automotive bailout in 2009, focused mainly on the needs of OEMs. Current federal and provincial funding is available through (a) newly established manufacturing and automotive-specific funds (including the Advanced Manufacturing Fund [AMF], the Automotive Innovation Fund, and the Automotive Supplier Innovation Fund) and (b) existing programs, such as the National Research Council's (NRC's) Industrial Research Assistance Program (IRAP) and business-led Networks of Centres of Excellence.[11] Through the establishment of several new funding programs, plus the support of some existing ones, efforts are being made to reconfigure southern Ontario's research infrastructure to support the renewal of its automotive and advanced manufacturing industry.

These efforts by both government and industry associations provide new sources of support to the large manufacturers (Automotive Innovation Fund) but are also designed to upgrade production and innovation capabilities among traditional automotive SMEs (Automotive Supply Innovation Program [ASIP])[12] and potential new entrants (Connected Car Project). In addition, efforts are being made to gradually shift the mandate of regional research institutions, including federal laboratories, universities, and community colleges, toward providing greater support for the applied research end of the TRL scale.[13] Nonetheless, manufacturing and automotive-related funds, such as the AMF for southern Ontario, face obstacles to their successful implementation, and others such as ASIP are still in their early stages. Funded by the Federal Development Agency for Southern Ontario (FedDev), AMF's goal is to promote the adoption of transformative advanced manufacturing activities, including both process and product innovation, through public–private collaboration. Announced in 2013, the program was rolled out slowly, with initial projects launched as late as 2015. According to Goar (2014, 1), manufacturers have found its rules "so onerous and restrictive, they discourage many innovative companies."

The next section outlines the shifting goals and metrics used to (a) evaluate funding applications by government agencies and programs and (b) implement projects by research institutions. The comparisons between research mandates reflect small differences that matter. For instance, the ASIP includes an automotive industry–specific mandate for TRL 8. No other industry or general advanced manufacturing program extends the reach of federal applied research assistance to this level. This could be critical for automotive SMEs who need market validation for their innovations. Finally, the section provides an overview of private initiatives that are also part of the current funding landscape.

National Research Council and Industrial Research Assistance Program

One significant recent development has been the reorganization of the NRC to focus on more applied research and to more closely resemble technology and innovation centres such as the Fraunhofer Institutes in Germany.

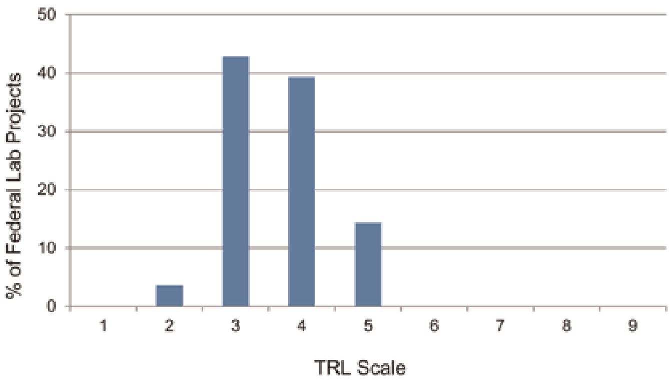

Figure 1: Federal Lab Projects (by Percentage on the TRL Scale)
Note: TRL = technology readiness level.
Source: Federal lab administrative files.[18]

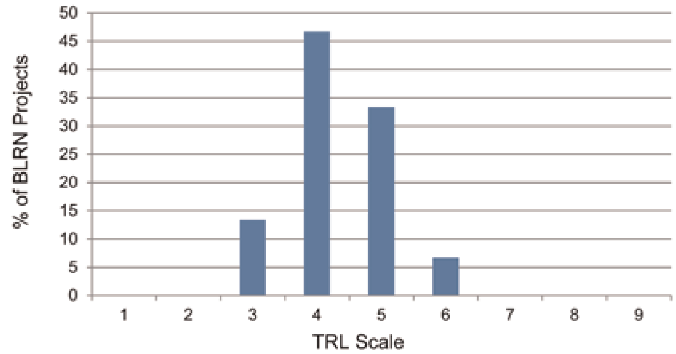

Figure 2: Business-Led Research Network Projects (by Percentage on the TRL scale)
Note: TRL = technology readiness level.

In the words of NRC's president, "It will now be an outward-looking organization with the goal of reducing the cost, time and risks for companies that want to carry out research and development" (Ivison 2013).[14]

Part of the federal government's effort to focus on industrial innovation was the doubling of NRC–IRAP funding to $220 million as part of the 2012 federal budget, with spending rising to $293 million in 2015–2016. The funding increase was to allow IRAP to introduce a new Concierge Service designed to connect SMEs to the most relevant services and programs necessary for them to grow through innovation. As with the manufacturing extension partnership (MEP) in the United States, IRAP provides technology advice, assistance, and services to SMEs to help build their innovation capacity. However, IRAP works with SMEs in any industry sector, including both manufacturing and high-tech services (Ezell and Atkinson 2011). Industrial Technology Advisors located in 150 regional offices in 90 communities across Canada provide advisory services to SMEs, but unlike the US MEP and UK Manufacturing Advisory Services (MAS) programs, they do not engage as much in deep firm-level interventions to transform SMEs' manufacturing practices (Shapira et al. 2011). Unlike the MEP and MAS, IRAP directly funds SMEs' R&D and innovation activities. As a result, its services tend to benefit those firms with existing research capacity rather than help shift a broader cross-section of SMEs onto a more innovative path.

Another concern is the limited coordination of efforts among various innovation support agencies to support the absorption of advanced manufacturing techniques among Ontario SMEs. A federal IRAP official interviewed was less generous when asked about coordination:

> No, the answer is no [there is no effort to coordinate]. We tried a few times, but these funding agencies work the same way as the dairy industry across Canada . . . : This is mine, and you can't touch it; I'm not going to let you get mixed into my decision-making process. In other words, this is my particular empire.

In addition to the funding program mentioned earlier, FedDev also provides funds for automotive suppliers to purchase new equipment through the Canadian Manufacturers and Exporters SMART program. Firms also rely on the Business Development Bank of Canada for funds for capital investments. Its more recent efforts include partnering with business accelerators to invest in start-ups that graduate into new businesses; the program was on track to achieve the $20 million target for fiscal year 2014.

Federal Labs and Business-Led Research Networks: The Move to Applied Research

Both federal government laboratories and some of the recently created business-led research networks are moving into the applied research field as part of the broader effort to provide greater support for firms in the automotive cluster. After a recent policy shift, some of the federal laboratories in southern Ontario are concentrating more resources and activity in TRLs 4–7. A prime example is a federal research laboratory that is dedicated to the development and commercialization of new technologies with potential applications in the energy, transportation, and metal manufacturing sectors. The mission of the laboratory has shifted over time from conceptualization and invention toward testing, assessment, and prototyping. Interviews reveal there was a qualitative change 10 years ago, when 80 percent of laboratory projects would have been at TRLs 1–2, toward the middle of the TRL scale (Figure 1). However, lab managers also say that the technology and engineering levels at which they operate mean that the potential pool of automotive SME partners for them is limited to 10 percent of the firms or less because of a lack of firms with the requisite innovation capabilities. Despite the shift in its mandate toward more applied research, this research organization continues to serve relatively larger customers from the automotive and related industries, raising questions about the extent to which these organizations can help upgrade innovation and production activities across the broader automotive supply chain.

Business-Led Research Network

The federal government is providing funds to a national business-led research network (BLRN) whose objective is to assist electronics manufacturers with the development and commercialization of advanced manufacturing technologies that have a broad range of potential applications. The network has a focus not just on large firms but also on SMEs. Although not specifically targeted at the automotive industry, the initiative could potentially help upgrade the innovation capabilities of a base of electronics suppliers to automotive or parts manufacturers. The initiative could be particularly valuable for the SME supply chain, considering the growing electronics system content of vehicles: "According to a report done by APRC … there are dozens of Canadian companies with expertise and, in many instances, innovations in electrical and electronics parts making potentially suitable for inclusion in the automobile of the future" (Yates 2015, 12).

Our interviews suggest that the potential contribution of the BLRN is still a work in progress. The objective of the network is to have all of its projects entering at TRL 4 and progress to TRL 7 over a 5-year period. As the data in Figure 2 indicate, they are well on the way to achieving this objective in terms of focusing on more applied research. Although the BLRN operates in a similar space as national laboratories, the strategy of the networks differs from existing initiatives in two critical ways. First, they organize their partnerships around a coalition of OEMs, universities, or colleges plus select SMEs with unique engineering or technology expertise. Second, the BLRN always includes an active manufacturing partner. In essence, the value chain of the BLRN partnership is the leverage for an accelerated rate of innovation. Therefore, BLRN managers expect that they can migrate through these stages at a much quicker pace than other research institutions, even when their portfolio of projects may closely parallel those of a government laboratory or academic institution. As such, the BRLN represents an innovative approach to bridging the gap between academic research capabilities and the need to upgrade the technological capabilities of firms along the automotive and advanced manufacturing supply chain.

Community Colleges

The primary emphasis on university–industry research collaboration has historically excluded many SMEs in southern Ontario from innovation networks, whereas the current mix of policy initiatives to support technology diffusion remain inaccessible to the vast portion of automotive SMEs. Although federal labs and business-led networks have shifted toward more applied research with the potential to draw a higher number of automotive SMEs into the process, the majority of the automotive supply chain lacks access to, or the capacity to benefit from, these institutions. An existing set of institutions with a strong track record of working with SMEs is Ontario's extensive network of community colleges, which have the potential to support technology diffusion across a broader group of manufacturing SMEs. The greater interest in the potential contribution of community colleges has been driven in part by a federal goal to strengthen the capacity of Canadian colleges as engines of economic growth and innovation working jointly with provincially legislated inclusion of applied research in college mandates across the country (Fisher 2009).

Scholars argue that Canadian colleges are in the process of "carving out a more conspicuous and aggressive role … within the national research and innovation agenda" (Bélanger et al. 2005, 31; see also Fisher 2009; Rosenkrantz 2013). Despite this potential, in Madder's (2005, 35) fourfold typology of developmental stages of research capacity, only a small number of Canadian colleges had reached the third and fourth stages of, respectively, "established" and "integrated" innovation institutions.[15] Furthermore, research indicates that the reality of college–industry collaborations occurs primarily on a much smaller scale, with partnerships consisting of SMEs and especially small enterprises, usually with fewer than 10 employees. These small local companies often approach colleges with issues related to economic survival, in which "adoption of new technologies may help companies simply to stay in business, and where world-beating applications are not priorities" (Fisher 2009, 24).

Interviews with community colleges and firms indicate that firms often use the services available to develop new ideas and prototypes, with improved production processes infrequently on the agenda (Samford, Warrian, and Goracinova 2015). An exception to these trends might be a community college in southern Ontario, where an advanced manufacturing centre has brought together large-, small-, and medium-sized firms to share best practices, develop new technology applications, and help mitigate the risks inherent in manufacturing processes. College administrators identified multiple, uncoordinated means by which businesses make contact with them. Most saw the arrival of their private-sector partners as ad hoc; they might be referred by provincial or federal agencies such as IRAP, they might be informed about programs by a business organization, or they might just be familiar with the local college and its programs through everyday experience. The inefficiency inherent in this process is borne out from the experiences of enterprises as well. One firm that ultimately ended up working with a community college indicated that it had initially sought help from a university in the United States because the IRAP administrators were unaware that the community college centre in their own municipality was working on the very same technology.[16]

Therefore, the degree to which Ontario's substantial community college infrastructure can be deployed to support the automotive industry and suppliers in particular remains largely untapped. The usefulness of a particular college to the automotive firms depends on the college's already existing capabilities, leadership, and the accompanying decisions each one makes as to its goals and private-sector interlocutors. On the basis of our findings, we conclude that, although levels of innovation support activities are expanding at community colleges, this growth is occurring in an unsystematic and uncoordinated manner.

Private-Sector Initiatives: The Connected Car and Electric Vehicles

An initiative explicitly designed to encourage intersectoral collaboration in southern Ontario's automotive cluster is the Connected Vehicle Technology Showcase or the Connected Car Project led by the Automotive Parts Manufacturers' Association and supported by the Ontario Centres of Excellence, a provincial government program. The province is also pledging an additional $500,000 in funding to the Ontario Centres of Excellence Connected Vehicle/Automated Vehicle Program, in addition to the $2.45 million in funding recently provided. The program brings academic institutions and business together to promote and encourage innovative transportation technology (Munim and Yates 2015).

Furthermore, in 2010, Natural Resources Canada commissioned an Electric Vehicle Technology Roadmap, researched and published by Electric Mobility Canada, an industrial association and consortium of fee-paying members whose objective it is to promote electrified transportation adoption, integration, and public investment. The Electric Vehicle Technology Roadmap states as its guiding vision at least 500,000 highway-capable plug-in electric-drive vehicles on Canadian roads, as well as what may be a larger number of hybrid electric vehicles.

More extensive large-scale investments in research, development, and commercialization of electrified and autonomous transportation technologies are undoubtedly needed to develop the supply chain and innovative ecosystem required for the next generation of automotive and transportation OEMs. Some of these investments are beginning to come from large multinationals, such General Motors (GM) and Siemens. In particular, GM Canada President Steve Carlisle recently announced,

> GM Canada will support the University of Waterloo's Engineering Faculty by providing $1 million to fund a Research Chair in advanced materials while also sponsoring engineering student Capstone design projects involving software development, which is key to GM Canada's work on "the connected car." (MacKenzie 2015)

Similarly, a substantial in-kind software grant from Siemens Canada to McMaster University could help meet the complex need of manufacturers in the automotive and related industries to improve their innovation capability (MacLeod 2015). This recent shift in corporate R&D activities represents a major new trend in upgrading the research and innovation capabilities of Ontario's automotive cluster. In part, these recent initiatives are building on the well-established capabilities of Ontario's research infrastructure. To truly effect a transformation in the innovation capabilities along the automotive supply chain, the impact of these new investments will have to reach much further into the supply base of SMEs that are the core of the automotive cluster.

Conclusion

Network failures have been identified as a reason for the lock-in of old industrial regions in mature technological trajectories. Recently, policy-makers, civil society, and private-sector actors have begun to support the introduction of more associative arrangements in traditionally non-coordinated economies, such as the United States, United Kingdom, and Canada. These collaborative projects often lie at the higher end of the TRL scale (4–7), strongly oriented to near-term commercialization in assisting companies to move toward widespread technology adoption. Nonetheless, there are noticeable variations in how these coordination arrangements have emerged in various institutional settings among the competitor regions that are missing from national-level studies of evolving industrial policies. As the evidence from our research suggests, these associative arrangements differ among various regions in Europe and North America depending on the role played by public- and private-sector actors and existing structural and institutional constraints, meaning that emergent forms of coordination are not fully defined by their national context.

The primary difference, although not necessarily the most important one, is between those policy mixes that continue to exclude SMEs from greater involvement with the intermediary institutions that support innovation along the automotive supply chain and those that facilitate their increased inclusion in evolving knowledge networks. The difference is particularly evident when comparing the portion of the automotive supply chain that has access to innovation resources in the regional research infrastructure of universities, government laboratories, and formal partner networks that are vital to the commercialization and diffusion of new technologies. Although we do not claim that these coordinating arrangements are the primary causal factor behind the renewal of the different automotive regions, they do appear to be an important element in their reinvigoration. A significant risk to the economic future of southern Ontario's automotive cluster is that most of SME firms in the automotive supply chain will not access the innovation assistance or shared public goods that they need for the future.

Variations in who benefits from these initiatives are relevant because it is the presence of SME-inclusive networks, whether privately or publicly led, that is important to regions where the automotive sector has recovered and is thriving. In other words, Ontario might draw lessons from ongoing developments in the competitor jurisdictions analyzed in this article to overcome the obstacles we have described in adopting new forms of networked arrangements to support innovation. Despite the presence of collaborative projects that support companies in the later stages of the innovation process, our evidence suggests that these remain largely inaccessible for the vast portion of automotive SMEs in southern Ontario. Interviewees indicate that only about 8–10 percent of SMEs are able to meaningfully engage with universities or government labs. This is because automotive suppliers are concentrated in the low value-added segments of the industry and lack the absorptive capacity to benefit from the new cluster resources.

Automotive clusters considered to be revitalized, such as those in the West Midlands or Detroit, are characterized by support for projects in the range of TRLs spanning concept to market, which is accessible to a significant portion of automotive SMEs.[17] This tendency has aided in cluster renewal, characterized by a growing segment of SMEs involved in all stages of the design and innovation process and, in particular, through the emergence of automotive engineering services clusters. Another point of difference between technological intermediaries in Canada, as compared with those in Germany, is that they are often initiated by civil society actors, as is the case with the community colleges, which apply for government funds in an effort to bring SMEs closer to emerging enabling technologies. Although there is greater reliance on public–private partnerships in recent initiatives, the Canadian case does not necessarily showcase greater coordination among initiatives or longer term financing. They have been decentralized and are not part of a coherent technological roadmap or automotive strategy. Future studies should delve into the precise reasons for the differences in coordinating arrangements and the degree of their impact on the ability of automotive regions to break away from incremental innovation strategies, if the goal is to do so.

Notes

1 This gap is alternatively known as a *commercialization gap* or the "valley of death" (Dasgupta and David 1994; Furman, Porter, and Stern 2002; Kaufmann and Tödtling 2001).

2 Government officials and entrepreneurs using the framework have identified the transition from the use of prototypes in a simulated environment (TRL 6) to the verification of prototypes in an operational environment (TRL 7) as the key challenge in upgrading firm innovation capabilities in the automotive supply chain.

3 The names of the federal research laboratory, university, community colleges, and the business-led research network are not disclosed for confidentiality reasons.

4 O'Sullivan et al. (2013), along with Andreoni (2015), identify shared characteristics of Networked Industrial Policy in Germany, Japan, the United Kingdom, and the United States, focusing on manufacturing policies in the post-2008 crisis period.

5 A recent report found that the US automotive industry could benefit from the recently established regional intermediaries part of the Network for Manufacturing Innovation designed to address needs that emerge as a product of the growing sophistication of manufacturing (Galvin, Goracinova, and Wolfe 2015). In a similar vein, the UK government has put forward a High Value Manufacturing (HVM) Strategy, a centerpiece of which are the Catapult centers meant to aid in commercialization.

6 Germany has released several high-tech strategies since 2006, including the widely referenced Industry 4.0 strategy.

7 These resources include machine shops and design firms developing the latest techniques; engineering firms providing product- and moment-driven support for a particular project; training and evaluation firms seeking to improve the quality of the workforce inside and outside the plants; and small- to middle-sized firms increasingly taking on the design, assembly, and delivery of whole parts of the finished automobile.

8 Major efforts include an International Business Center designed to assist SMEs in becoming export ready while simultaneously attracting international investment to the region and a Technology Center intended to accelerate the commercialization of new technology by bringing together businesses, academics, and government. Automation Alley is also home to a Michigan-wide network of regional associations of technology professionals.

9 They include 14 Fraunhofer institutes, which conduct applied research for larger firms, and the 300 Steinbeis foundation transfer centers based in higher education institutions and innovation centers, which work largely with SMEs. It is also important to integrate the domestic innovation system with overseas suppliers, customers, and strategic partners to access global knowledge flows. With the global restructuring of the automotive manufacturing industry, Stuttgart has benefited from both its strong export orientation in

the sector and the decision of the major players to turn Stuttgart into a worldwide hub for car manufacturing.

10 Developments at several of the OEMs in the past decade suggest that this pattern is gradually starting to shift toward more regionally embedded innovation through the establishment of more firm-led R&D facilities in Windsor and the Greater Toronto Area and with a higher level of partnering with Ontario research institutions, but the change has occurred relatively late compared with its competitor jurisdictions.

11 Relevant provincial programs include (a) the Jobs and Prosperity Fund (>40% of the funds it has spent so far went to automotive manufacturing), (b) the Southern Ontario and Eastern Ontario Development Funds, and (c) the Automotive Supplier Competitiveness Program, specifically targeted to automotive suppliers.

12 The fund is not exclusively focused on traditional automotive SMEs, and a substantial amount of the funding has been allocated to non-traditional automotive suppliers.

13 As noted at the outset, a notable part of these developments has been the increasing adoption of TRLs as part of the *lingua franca* of research policy, funding criteria, and the evaluation of research and technology development projects (ISO 2013; Mankins 1995).

14 At the time of writing, the president of NRC had resigned and a new president had just been appointed by the federal government. It is unclear whether he will continue to push NRC in the direction initiated by his predecessor.

15 Established innovation colleges have comprehensive policies relevant to applied research, including (a) fiscal management, (b) human resources and reporting, and (c) facilities and equipment, and integrated innovation colleges also have long-standing business support systems.

16 Similarly, Samford, Warrian and Goracinova (2015) document the efforts necessary for a single business to uncover the services required to create a prototype and begin production of an industrial fastener.

17 This is both because initiatives explicitly aim to support firms in the low value-added segments of the industry (e.g., SMMT Industry Forum) and because of the heavier presence of technology-intensive suppliers.

18 Data derived from confidential administrative files.

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Appendix

Table A: Technology Readiness Levels

TRL Level	Description
1. Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Example might include paper studies of a technology's basic properties.
2. Technology concept or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative, and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.
3. Analytical and experimental critical function or characteristic proof of concept	Active research and development is initiated, including analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component or breadboard validation in laboratory environment	Basic technological components are integrated to establish that the pieces will work together. This is low fidelity compared with the eventual system. Examples include integration of ad hoc hardware in a laboratory.
5. Component or breadboard validation in relevant environment	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include high-fidelity laboratory integration of components.
6. System or subsystem model or prototype demonstration in a relevant environment	Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated operational environment.
7. System prototype demonstration in an operational environment	Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as in an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.
8. Actual system completed and flight qualified through test and demonstration	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine whether it meets design specifications.
9. Actual system flight proven through successful mission operations	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last bug-fixing aspects of true system development. Examples include using the system under operational mission conditions.

Note: TRL = technology readiness level.
Source: Public Works and Government Services Canada (2016).

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