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ABSTRACT

The global automotive industry is currently experiencing the greatest disruption it has faced in over a century. The advent of connected, autonomous and electric vehicles and the popularity of ride sharing services are transforming the industry to one that is increasing referred to as transportation as a service (TaaS), transforming the customer experience and potentially shifting the entire industry sector away from private modes of transportation. Substantial uncertainty exists as to whether traditional automotive hubs in Automotive Alley will remain central to the growing digitization of the automotive industry or whether they will be replaced by new geographies with greater strength in digital technologies. This paper explores the extent to which efforts currently underway in the southern Ontario automotive cluster to meet the challenge of digitization in the auto industry are laying the foundations for a process of new path creation or modernization and institutional reconfiguration. The paper argues that the strength of Ontario's regional innovation system (RIS) and growing OEM R&D investments provide expanding opportunities for the cluster to remain competitive either by 1) firms upgrading or moving up the value chain by strengthening skills and production capabilities; or 2) modernizing on the basis of connected or electric vehicle technologies or organizational innovations. The focus of the study are the current efforts on the part of OEMs to adapt to this rapidly changing technological paradigm and the role played by current federal and provincial policies to intensify regional knowledge linkages. The paper concludes with a discussion of the possible trajectory for the future development of the region's automotive cluster.

Key words: regional resilience, path development and transformation, regional innovation policies, connected, automated and electric vehicles, automotive sector, Ontario, Canada.

JEL codes: O (O1, O2, O3), L (L1, L6, L9), P

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Introduction

The global automotive industry is currently experiencing the greatest disruption it has faced in over a century. Not since the introduction of the Model T and the consolidation around the internal combustion engine has the industry been challenged by the convergence of so many interlinked new technologies, involving new products, processes and organizational innovations. Increasingly, experts in the field describe the impact of the innovations in terms of four interlinked technologies– connected, autonomous, electric and shared mobility systems. While there is considerable dissent among industry experts over the pace at which these new innovations will diffuse, there is little disagreement that change is definitely coming and that no existing producers will be unaffected by its impact.

The advent of connected, autonomous and electric vehicles and the popularity of ride sharing services are transforming the industry to one that is increasing referred to as transportation as a service (TaaS), transforming the customer experience and potentially shifting the entire industry sector away from private modes of transportation. Automotive players know that the battle for long-term profitability involves partners not previously linked to the traditional automotive sector value chain, such as emerging firms in the software sector, new urban innovation firms, like Alphabet subsidiary, Sidewalk Labs and public sector organizations that will influence how the new modes of transportation are regulated and adopted in urban settings.

It appears that firms are pursuing profitability in these evolving forms of urban mobility by establishing new ecosystems in which heterogeneous players (including potential competitors) need to interconnect with unknown consequences and in a short timeframe. The focus is not just on hardware or software to deliver these exciting new mobility solutions, but new operating models involving integrated solutions provided by many partners within a digital ecosystem. It requires resources, time and a certain mindset to successfully engage in ecosystem creation, and it conflicts with the traditional conceptions of the drivers of growth strategy and the framing of partnerships. The emerging innovation models being adopted differ radically from the traditional global production/innovation networks that have dominated the automotive sector since the 1960s.

The implications of this change will be profound for those regions with strong capabilities in the production of automobiles under the predominant ICE technology paradigm –

in North America, this means the provinces and states that comprise "Automotive Alley", stretching from Ontario in the North through the Midwest to Alabama and Mississippi in the deep south. Substantial uncertainty exists as to whether traditional automotive hubs in Automotive Alley will remain central to the growing digitization of the automotive industry or whether they will be replaced by new geographies with greater strength in digital technologies, such as northern California, home of Tesla, Google, Cruise and other start-ups who are moving into the automotive space. In the face of this challenge, many analysts argue for the continued strength of established auto makers based on their deep competences in a wide range of technologies and production techniques intrinsic to the automotive industry. Their traditional manufacturing competencies affords them a competitive advantage as they adapt to the changing technological landscape through enhanced investments in R&D, next generation manufacturing power train and materials technologies, as well as leveraging the intrinsic research and innovation capabilities of their regional public and private research institutions.

This paper explores the extent to which efforts currently underway in the southern Ontario automotive cluster to meet the challenge of digitization in the auto industry are laying the foundations for a process of new path creation or modernization and institutional reconfiguration. Ontario's regional innovation system provides unique opportunities for new entrants to the automotive industry and for existing firms to upgrade their operations – considering the presence of a strong research infrastructure and diversified industrial structure. Policies put in place over the past decade have tried to utilize existing resources to both help modernize the automotive sector, but also support established automotive suppliers. There has been a proliferation of technology push initiatives to increase R&D competence among both traditional suppliers and new entrants. What is unclear yet is the extent to which new digital technologies will be applied in Ontario to launch the automotive industry on a new path or whether and how existing suppliers will utilize the growth opportunities associated with the adoption of new technologies.

There is growing acknowledgement, in both corporate and public policy circles, that the Province of Ontario is a jurisdiction with superior automotive R&D capabilities and high-quality production operations, related to its strength in both traditional engineering disciplines, as well as emerging digital technologies. In a recent submission to the federal Innovation Agenda review process, the Canadian Automotive Partnership Council (CAPC), representing the OEMs, said that “In face of these global manufacturing head winds, innovation must become THE pathway to automotive industry growth in Canada . . . . (but) we have not historically focused on Canada as a growth location for invention, research & development (R&D) and engineering of new automotive products and technologies” (Canadian Automotive Partnership Council 2016).

This new agenda represents a fundamental shift in perspective for the relationship between the multinational enterprises (MNEs) that have dominated the automotive sector in Ontario since the 1920s and the innovation and production capabilities of the host location. Current research on the changing calculus of MNE’s global strategy with respect to host locations suggests this is part of a broader pattern of change in the way in which MNEs allocate research and production activities to different regional economies as the knowledge base of even the most Fordist industry is disrupted by the effects of the digital revolution. In the face of this challenge, many analysts argue for the continued strength of established auto regions based on their deep competences in a wide range of technologies and production techniques essential for automotive production. The literature on path dependence and regional resilience provides a critical lens through which to analyze this development by suggesting that the future of the automotive sector will depend on the dynamic evolution of the institutional setting in which the industrial cluster is located (Boschma 2014).

This paper explores the extent to which efforts currently underway in the southern Ontario automotive cluster to meet the challenge identified in the CAPC submission are laying the foundations for a process of new path creation or modernization and institutional reconfiguration. OEMs have begun to play a leading role in this potential shift toward path modernization with the support of financial incentives from governments. Part of what is starting to occur involves a process of the OEMs looking to upgrade the range of activities that their subsidiaries undertake in Ontario by engaging much more directly with the cutting-edge research base of Ontario’s post-secondary educational sector. Modernization activities are still in their initial stages and the degree to which OEMs will continue to focus on Ontario as an R&D location is unclear, but the current trend indicates a significant break with the past developmental trajectory of the province’s automotive sector.

The paper argues that the strength of Ontario’s regional innovation system (RIS) and growing OEM R&D investments provide expanding opportunities for the cluster to remain competitive either by: 1) firms upgrading or moving up the value chain by strengthening skills and production capabilities; or 2) modernizing on the basis of connected or electric vehicle technologies or organizational innovations. The focus of the study are the current efforts on the part of OEMs to adapt to this rapidly changing technological paradigm and the role played by current federal and provincial policies to intensify regional knowledge linkages. The willingness of OEMs to connect with the Canadian start-up scene and the resilience of established automotive suppliers indicate the potential for the emergence of a revitalized and innovative automotive ecosystem. The paper begins with a discussion of the evolutionary economic geography literature on new path creation and identifies potential trajectories for the automotive cluster given Ontario's regional innovation system. It continues with an investigation of the initiatives targeting both OEMs and the supply chain and ends with a discussion of the possible trajectory for the future development of the region's automotive cluster.

Path Dependence, Regional Resilience and New Path Creation

A critical issue for the way in which regional economies evolve over time is the relative impact of path dependence on their pattern of development. Within evolutionary economics, the concept of path dependence has been used to explain why certain technologies prevail in the competitive setting of the marketplace, although they may not always be technologically superior (Arthur 1994). The evolutionary approach argues that economic systems change over time, but in ways that are shaped and constrained by past decisions, random events and accidents of history. The concept is somewhat counterintuitive in that it purports to explain how structured patterns of development – across time and space – can result from seemingly random or chance occurrences. However, the challenge is to reconcile the significance of random or chance events in endowing a region with its specific industrial structure and institutional capabilities, while allowing for the role of individual and collective agency in fashioning subsequent changes in its broader institutional structures and development strategies.

The path dependent nature of development in regional economies, involves the process by which new paths are created and existing institutional ensembles begin to break down or decay. Central to the question of regional resilience is how adaptable these institutional ensembles are to changes in the principal industries and technologies at the core of the region's industrial structure. The key issue concerns the ability of firms, industries and institutions in a specific region to adapt their existing knowledge base and localized capabilities to the generation and exploitation of new commercially valuable sources of knowledge. “New paths do not emerge in a vacuum, but always in the contexts of existing structures and paths of technology, industry and institutional arrangements” (Martin and Simmie 2008, 186). Resilient regions tend to be those in which existing clusters of firms prove adept at transitioning out of declining industries, while simultaneously exploiting the local knowledge infrastructure to cultivate new, potential growth fields. In both instances, the support of local and regional institutions is critical for those capabilities.

While they don’t explicitly reference the concept of path dependency, Maskell and Malmberg extend this point by arguing that the competitive success of firms depends on distinctive, localized capabilities. These capabilities arise from regional assets that are non-ubiquitous, or unique to the region. They can be based on the infrastructure and built environment of the region, its endowment of natural resources, the regionally-specific institutions and the available set of knowledge and skills. A region’s institutional architecture accumulates and changes incrementally and represents the interaction between various elements that have been built up or accumulated over time. Because of these properties, this institutional endowment can become a key part of a region’s non-replicable asset base, thereby reinforcing durable local competitive advantages that are difficult for competitor regions to emulate,

> . . . it is the region’s distinct institutional endowment that embeds knowledge and allows for knowledge creation which . . . constitutes its capabilities and enhances or abates the competitiveness of firms in the region. The path-dependent nature of such localised capabilities makes them difficult to imitate and they thereby establish the basis of sustainable competitive advantage (Maskell and Malmberg 1999, 181).

The literature on regional resilience draws extensively from this perspective on path dependence. The evolutionary approach attaches great importance to the institutional underpinnings of resilience and the extent to which political and civic institutions may frame the responses taken by different regions to the natural, economic and social disruptions they encounter. Finally, it recognizes the extent to which regions are embedded in broader political geographies and that these ‘nested scales’ shape and constrain both the potential for, and the actual way, in which they respond to external shocks (Pike, Dawley, and Tomaney 2010; Bunnell and Coe 2001). Pike et al. draw a distinction between the concepts of adaptation and adaptability. Adaptation is seen as a short-run phenomenon that involves the movement back towards the original path of development based on strong linkages between different social agents and the institutional underpinnings of the regional economy. In contrast, adaptability involves the capacity to shift the growth path of a region towards multiple and alternative trajectories of development, based on the ability to forge new linkages between social agents and alternative or emerging institutional structures. Adaptation involves the region's ability to adjust to a new competitive dynamic in the global economy in order to maintain a previously successful growth pattern, whereas "resilience through adaptability emerges through decisions to leave a path that may have proven successful in the past in favour of a new, related or alternative trajectory" (Pike, Dawley, and Tomaney 2010, 62; Simmie and Martin 2010). Over the long run, adaptability involves the ability to transform its industrial structure, labour market, productive technologies and supporting institutions to respond to external pressures and take advantage of new economic opportunities.

Another factor that conditions the resilience of regions is their institutional underpinnings. Central to the changing role of the regional scale in facilitating the adjustment to a changing economic environment is how institutional ensembles adapt to changes in the principal industries and technologies at the core of the region's industrial structure. This concerns the ability of firms, industries and institutions to adapt their existing knowledge base and localized capabilities to the generation and exploitation of new commercially valuable sources of knowledge. Resilient regions are those in which existing clusters of firms prove adept at making the transition out of declining industries or technologies, while simultaneously exploiting their local knowledge infrastructure to cultivate new, potential growth fields. Their pattern of development is strongly influenced by the industrial strengths of the current economy, as well as by the broader set of institutions that have supported those sectors. Those sectors in which an urban or regional economy has historically been specialized will constrain its future ability to grow or create opportunities for new sectors to emerge. The basis on which those sectors can emerge will be influenced, in turn, by the capacity of firms and institutions within the region to develop and exploit new sources of knowledge and their existing knowledge infrastructure, as well as the talents and skills of the work force (Wolfe 2010).

By example, in investigating institutional changes in Baden-Württemberg's automotive cluster, authors have noted the significance contribution of developments such as the Automotive

Simulation Center, aimed at enhancing the degree of science-industry cross-sectoral collaboration in the region. The goal is to coordinate and integrate knowledge using and exploring processes by establishing cognitive proximity among individual actors and communities at the firm level. According to Strambach and Klement, such developments present neither a complete disruption of the established incremental improvement trajectory, nor the rise of completely new actors, but rather a gradual reconfiguration of the institutional architecture of the region (2013). This helps create opportunities to explore new links between complementary industries and technologies to enhance the resilience of the regional automotive industry.

Recent research has taken this line of thinking a step further in suggest that institutional innovation may be as important, if not more important, for new path creation than the ability to transition into new technologies. There are several reasons why the legacy of organizations and institutions can significantly affect the potential for new path creation in lagging regions. Features of the initial conditions under which institutions or organizations are formed can become enduring constraints. The organizational structure can become locked-in to a comparatively narrow subset of routines, goals, and future growth trajectories. Historical precedent shapes the whole institutional matrix because each new component is adapted to fit with the elements of the pre-existing structure, giving rise to a strong degree of persistence among structures as the ‘sunk costs’ of abandoning them becomes excessively high (Sotarauta and Suvinen 2018, 90–91). The scope for reversing previous choices can restrict opportunities for forms of path development over time (David 1994). New path creation may thus require active entrepreneurial intervention by a range of actors, including those in the scientific and policy spheres that lie beyond the normal category of business entrepreneurs. Building on this perspective, Sotarauta and Suvinen divide institutional agency into two categories — institutional entrepreneurship and institutional navigation. The former refers to “conscious efforts to pool and mobilize resources and capabilities to create and/or change institutions”, while the latter “focuses on the ways that actors deal with mixed messages of many institutions . . . all the time formulating and implementing their own strategies” (Sotarauta and Suvinen 2018, 90–91). In a case study of Tampere, Finland they conclude that the process of new path creation depends upon institutional agency by entrepreneurial actors from a range of sectors to shape new economic opportunities. In the process, actors acquire new ways of viewing the economic situation of their cities or regions and constructing new economic opportunities. Over time, the new sets of institutions or organizations created become embedded in the region and can unlock a range of new economic opportunities.

Drawing on the work on path dependence, regional resilience and the cluster life cycle, several scholars, including Martin and Simmie (2008) and Boschma and Frenken (2005) explore the different trajectories that are possible for regional economies to transform their own developmental paths. Inspired by Boschma's work on related and unrelated variety (2014), Trippl, Asheim and Miorner (2015) initially suggested that there are three main paths to regional industrial renewal. The first, *path extension*, occurs through incremental innovations adopted by existing firms in a regional cluster or sector. However, the challenge for such a form of path development is whether the incremental innovations are sufficient to offset the challenges faced by the region from new lower cost production regions (in the case of Ontario, the southern U.S. states and Mexico) or newer more innovative production regions (in this case Tesla in California, plus the growing efforts by the OEMs to transform their existing production base in Michigan). Regional economies that are locked into an existing set of production techniques, which rely on an existing knowledge base and are limited to incremental innovations, may find they have limited opportunities to rejuvenate the existing sector or cluster, leading eventually to stagnation and regional *path exhaustion*.

The second pattern of path development occurs when local firms and industries are successful in making the transition into related sectors and activities along the lines suggested by Boschma and Frenken in their work on regional branching and related diversification. This type of path development, referred to as *path branching* involves the transition from existing regional knowledge bases and areas of production expertise or competence into industries or sectors closely related to the existing areas of knowledge, competence and expertise. The third route labelled *new path creation* corresponds to Boschma's concept of unrelated diversification. It involves the emergence of new firms in unrelated knowledge areas with limited pre-existing competence in the production techniques of the existing industry sectors or clusters. New path creation is often based on novel areas of research and as such relies much more strongly on what Asheim and Gertler refer to as the analytical, rather than a synthetic knowledge base (2005), or what Lundvall refers to as the STI mode of innovation as opposed to the DUI mode of innovation (Lundvall 2006). While it is possible for new path creation to occur in older industrial regions, it more frequently occurs in new regions where the novel research is being carried out and where the existing industrial structure and supporting institutions are not encumbered with an entrenched mass of incumbents in the sector. Storper and Walker (1989) describe this geographical dimension of the process of technological innovation as the opening of 'new windows of locational opportunity'.

In recent work Isaksen, Tödtling and Trippl (2018) introduce two additional modes of path development to this typology, both of which are highly relevant for the study of the Ontario automotive cluster: *path importation* and *path modernization*. Path importation involves a major change of a path related to the inward investment by new foreign companies or the inflow skilled immigrants bringing new competencies not previously available in the region. It can also lead to a repositioning of the place of the region in global production networks (GPNs), moving up the value chain based on upgrading of skills and production capabilities. *Path modernization* involves a major change of a path into a new direction based on the infusion new technologies or major organizational innovations in the region (2018, 225-27). Based on our analysis of the Ontario case, described below, we suggest the possibility of a sixth mode of path development in a regional economy: *path hybridization*. This occurs in a situation in which the technological capabilities of two previously distinct economic sectors – in this case the automotive and the information and communications (ICT) sectors – begin to converge around a new set of technologies. As a result of the convergence, the distinct sectors are transformed as the integration of a novel set of technologies from one sector becomes the driving force in transforming the production model of the other sector. The critical issue in analyzing the current development of the automotive sector in Ontario is to assess whether the changes underway reflect one of the five modes of path development previously identified in the literature or whether it, in fact, reflects a new distinctive mode of path development, which we label *path hybridization*.

Also relevant for understanding the alternative developmental paths open to regions are the insights afforded by recent research on the changing relationship between multinational enterprises (MNEs) and their host locations in the context of the knowledge-based economy. A significant body of research dating back to the 1980s documents the shifting relationship between subsidiaries in host locations and their parent MNEs as the subsidiaries have been given broader mandates to pursue "asset-seeking" or "asset-augmenting" strategies. In this approach, subsidiaries have been granted increasing scope to pursue competence-creating investment strategies in the view that the host location is not just a market for the home country's products, but a potential source of competitive advantage for the MNE. According to Cantwell, this stream of research depicts "the MNE as an international network for geographically dispersed innovation" which stresses "the dynamic connectedness between local knowledge creation and exchange in each node of the network" (Cantwell 2009, 36). While the asset augmenting strategy can be implemented in a host economy through the process of path importation discussed above, it is also possible that existing MNEs in a region can adopt this approach.

This change involves a shift in the role of the MNE as an institutional mechanism for transferring new technologies across national boundaries to a role as the creator or the system integrator for new technologies in discrete national and regional jurisdictions (Dunning 1996; Cantwell 2013). For this strategy to succeed, the local subsidiary must become embedded in its own local network of research activity and competence building, in other words, in a distinctive innovation ecosystem. As MNEs shift their innovation strategy to one of networked technology integration, they become more interested in producing in locations that provide access to complementary innovation capabilities. From the perspective of the firm, the goal is to link a range of high-value-creating activity across a number of different nodes or centres of excellence that collectively form the international network of the MNE. This results in the construction of an integrated portfolio of locational assets across a range of host countries or regions in which the MNE is embedded. This evolving rationale for MNE investments suggests a new strategy for corporate diversification in which the MNE can create new value by linking a series of interdependent subsidiaries and research centres into an evolving range of complementary activity (Cantwell 2009).

> The trend towards more complex knowledge systems and technology fusion across formerly separate fields of development has generated increasing interconnectedness between intra-firm and inter-firm networks, . . . A rising technological distance of knowledge combinations and greater local subunit creativity leads to search being conducted across organisational boundaries, especially when such search is geographically localised (Cantwell 2017, 48).

Cantwell suggests that there may also be a competitive rationale for industry leading MNEs not to locate their technology development activities in the industrial home base of their major international competitors (2017, 44). This strategy of differentiating their regional sources of research expertise may also create the opportunity for new innovation and development strategies for the regional economies in which the MNE is based. This may be particularly true in the case of new or emerging technologies at the core of the current techno-economic paradigm (ICTs) that are not an area of research excellence for the MNEs home base (Cantwell 2017, 46; Freeman and Perez 1988). This strand of research on the relations between MNEs and host countries suggests a connection with the literature on new path creation. In regional economies able to leverage their unique, or non-ubiquitous, research assets and competence building capabilities, there is a potential to attract new investments by MNEs to access local capabilities as a core element of the MNEs global innovation strategies. Regions that prove successful in pursuing this route may be able to leverage new corporate investment to help move onto a path modernization trajectory.

Knowledge linkages and Path Development in Ontario's RIS

To conceptualize current changes within the Ontario automotive cluster, we adopt a typology of the linkages possible within Ontario's RIS. The goal of the typology is to indicate that with growing local and global linkages, where new path creation is occurring through the mode of path hybridization identified above. The framework locates the degree of firm-RIS interaction on the vertical axis and two spatial dimensions of knowledge sources: local knowledge networks and global knowledge linkages on the horizontal one. The vertical axis of Table 1 (below) runs from: 1) a territorially embedded RIS where local firms have little connection to regional knowledge organizations, to 2) regionally networked systems where policy interventions aim to strengthen the regional institutional infrastructure support for firms' innovation processes, and finally, 3) regionalized national innovation systems where innovation activity often takes place in cooperation with actors outside the region (Cooke, 1998). The changes discussed below provide some evidence of a transformation of the Ontario automotive cluster from a territorially embedded one to a regionally networked one where local firms are progressively relying on knowledge institutions for research, technology adoption and training purposes in response to policy interventions.

Table 1: Trajectories of Path Development for Ontario's RIS

Governance of Regional Innovation Systems/ Knowledge linkages	Globalized	Interactive	Localized
Territorially embedded	Ontario automotive supply chain (before 2000) →Low value added → Little to no OEM research		
Regionally networked		Ontario automotive supply chain in transition? → supply chain in higher valued added segments → OEM research → new firm entrants	
Regional Nationalized			

The horizontal axis, meanwhile, moves from the local spatial dimension of knowledge to global knowledge linkages, which include knowledge flows from inward foreign direct investment (FDI) to local firms (see Bathelt et al. 2004). Categorizing Southern Ontario as reliant on interactive knowledge linkages implies that in addition to the importance of local networks, inter-firm collaboration and knowledge flows, global knowledge linkages are increasingly relevant as knowledge flows from the MNEs' R&D and foreign training programs to local firms. At the same time, however, it is becoming apparent that the increased R&D investments by MNEs are designed to tap into the existing strengths of the region's post-secondary research infrastructure, as well as the emerging strengths of its start-up and scale-up innovation ecosystem.

Previous research has characterized Ontario's RIS as undergoing a transition to a more networked one with institutionalized knowledge linkages, but with a considerable way to go to become fully networked (Gertler and Wolfe 2004). The intervening decade and a half has seen that trend intensify and the initial promise it held begin to bear fruit. The current Ontario RIS is characterized by a diverse set of capabilities and a thick organizational landscape. It hosts a relatively large number of different industries and a critical mass of knowledge and supporting organizations that promote innovation and development in a wide range of economic and technological fields, with a growing network of intermediary organizations to support the innovation process. We argue that the institutional and industrial variety in these types of regions have high potential for cross-sectoral knowledge flows and new recombination of knowledge (Boschma 2014).

Trippl and Isaksen (2016) suggests that diversified and institutionally thick regions are the ones most likely to experience path upgrading and path modernization. This point is consistent with the observations of the automotive sector in Ontario, where John Holmes (2016) has characterized the current choice for the sector as one between resurrection and reinvention. Resurrection primarily involves the competitiveness of the manufacturing base for the OEMs in Ontario, particularly, the advanced processes that utilize robotics, computer systems, complex sequencing and logistics in the production and assembly of automobiles. In contrast, reinvention involves a process of new path creation with respect to auto product engineering and R&D through what we are labelling *path hybridization* – namely the process of inventing, testing, integrating and optimizing a wide range of new products and services that is highly dependent on the broader regional `innovation ecosystem': engineering talent, research alliances, IP policies, R&D tax credits and other state support for company based innovation, etc. (Holmes 2016). In this process of reinvention through *path hybridization*, the future of Ontario's automotive sector may very well depend on the ability of the existing OEMs that dominate the sector to establish effective linkages with emerging start-ups from well outside the traditional automotive sector. It is important to understand that what makes this distinctive mode of new path creation possible in Ontario is that it enjoys competitive strengths in both sectors involved – automotive and ICT – a factor that is not shared by other jurisdictions with strength in one sector or the other, such as Michigan and California.

Ontario's RIS provides unique opportunities for new entrants to the automotive industry and for existing firms to upgrade their operations – considering the presence of a strong research infrastructure and diversified industrial structure. Although not entirely the result of policy changes, there is growing evidence to suggest a degree of institutional change is occurring in the automotive innovation system, in the form of an intensification in the relationship between firms and regional innovation organizations. A recent survey demonstrates that around a third of SMEs and OEMs in Ontario engage with the regional knowledge infrastructure. The pace of institutional change is slow and there are continued critiques of lagging R&D investment and hostile OEM-supplier relationship, while innovation in the supply chain remains incremental. In this context, policy efforts aim to target both established automotive firms and new entrants in the electric and connected vehicle market.

There is growing consensus that adaptation in the form of resurrection identified by Holmes will not prove sufficient to secure the future of Ontario's automotive cluster. This is leading to increasing joint efforts on the part of OEMs, business associations (CAPC, the Automotive Parts Manufacturers Association (APMA)) and academics from a cross section of post-secondary research institutions aimed at the reinvention of the sector. These emergent investments are often incentivized and supported through federal and provincial policies, which initiatives are discussed in the paper. Overall, actors have worked to upgrade Ontario's thick institutional setting and the capabilities of its knowledge infrastructure – including universities, community colleges and innovation intermediaries, such as the Ontario Centers of Excellence (OCE), but also to create and support the linkages it has with its diverse industry sectors, including automotive firms or potential new entrants from Ontario's dynamic ICT sector. In some cases, this involves establishing new organizations, but also layering new functions on existing institutions (particularly the changing roles of universities and community colleges as they are expected to perform more industry-relevant applied research).

Although the Ontario automotive cluster is departing from its traditional organization basis, making this new mode of *path hybridization* possible, it is still fraught with considerable uncertainty. This is especially the case in light of the focus on R&D activities, while there are few efforts to integrate new technologies into prototype development and there is often no requirement that firms demonstrate the ability to commercialize the technology being funded by drawing on existing expertise in the automotive supply chains. Obstacles to the commercialization of new technologies in Ontario's innovation system include: the past history of limited collaboration between the OEM's and Ontario's research infrastructure; increased pressure on the OEM's to concentrate more of their production and research activities in their home territory; conflictual OEM-supplier relationships; and a relatively weak history of building collaborative innovation networks. Despite these obstacles, we observe growing evidence that Ontario's automotive innovation system is beginning to transition to a different developmental path than it has pursued historically.

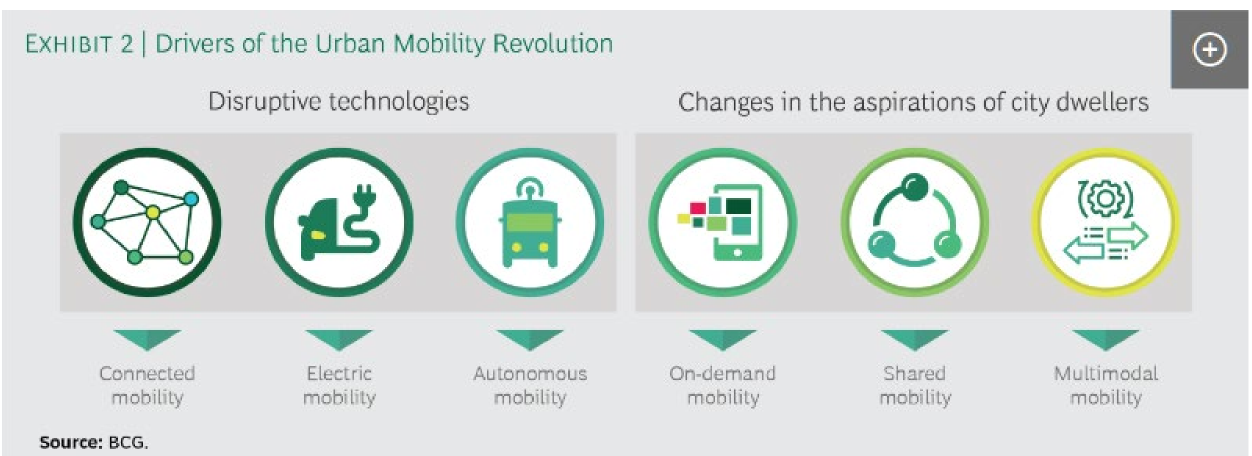
Path Hybridization and the Future of Ontario's Automotive Sector

The presence of Ontario's automotive cluster dates to the establishment of Ford's Canadian subsidiary in the first decade of the 20th century and the founding of Sam McLaughlin's Motor Car Company in Oshawa in 1908 (purchased by General Motors in 1918). Ontario has been the site of a significant proportion of North America's auto assembly since the negotiation of the Auto Pact with the U.S. in 1965 and major investments by two Japanese OEMs in the 1980s. However, historically the auto sector was most striking in that the predominance of the 'Big Three' OEMs, plus Toyota and Honda generated virtually no domestic R&D performed in Ontario, despite its significant weight in the provincial economy and the substantial proportion of North American production accounted for by the province. In the words of the former President of GM Canada, Steven Carlisle, Ontario was completely reliant on technology developed elsewhere for the cars it assembled, not a recipe for success in a knowledge-based and innovation-intensive economy. This reliance on foreign technology in Canada's largest manufacturing sector has been identified as one of the key factors explaining the low levels of business R&D (BERD) in Canada (Council of Canadian Academies 2009). However, this same factor has begun to change in the last three to five years as the OEMs reassess the basis of their relationship to the host region of Ontario. This development is in keeping with a broader trend in the changing relationship between MNEs and host regions described by Cantwell and others.

The increased attention to local and regional R&D capacity by U.S. OEMs is part of a broader response by the MNEs to the challenge of responding to the enhanced digital capabilities in automobiles – the emergence of the automobile as a new digital platform or the emergence of connected and automated vehicles (CAVs) – as well as the pressure exerted by tighter emissions regulations that is driving research on light weighting materials and alternative energy sources. This pressure is leading to increased R&D activities by the OEMs in a growing range of host jurisdictions, including Ontario, where there is also a move toward higher value-added segments of the industry (electrical and electronics parts) by automotive parts suppliers. In a speech to the J.D. Power 2016 TalkAUTO Canada conference, Steve Carlisle, the former President and Managing Director of General Motors of Canada, outlined the basic contours of the research strategy that the company was pursuing both in the U.S. and in Canada.[1] The key to the strategy is to disrupt itself before it is disrupted by a wide range of new start-up companies. GM's vision for its future rests on four pillars: one that is electric, connected, autonomous and part of the sharing economy. The shift to the connected car is a critical part of that transition. They see digital technology doing to the automobile what the smart phone has done to communications over the past decade.[2] Because of this, they are actively searching for potential partners and research capabilities that can accelerate their introduction of autonomous capabilities in their vehicles.

An array of new government funding programs have emerged to support research into automotive-related digital technologies, alternative energy sources, and new lightweight materials - especially in the US and Europe (Galvin, Goracinova and Wolfe 2015). The chart below provides a visual representation of how leading consultancy companies envision the future of the automotive (including automotive parts) industry.

Figure 1. Re-inventing the wheel – Scenarios for the transformation of the automotive industry



Source: Hazen, Reeves and Marteau, 2018.

[1]See full speech at: http://media.gm.ca/product/public/ca/en/gm/home.detail.html/content/Pages/news/ca/en/2016/Nov/1109_JDPower.html

[2] They believe that most new car buyers expect for the automobile to be a mobile device and are moving rapidly to enhance connectivity in their cars. But they also see connectivity and the move to autonomous vehicles as a safety issue with the potential to significantly improve the safety features of their vehicles.

Policy incentives and Automotive R&D trends in Canada

Ontario has historically been primarily a production location, rather than an R&D centre, due to a set of structural conditions including: 1) the ownership structure of the industry, 2) the scale of the Canadian parts sectors, as well as 3) the tariff structure. Landmark agreements such as the Canada-US Auto Pact also prioritized production over innovation-related activities (Anastakis, 2005). Canadian vehicle production, however, has contracted over the past two decades in the wake of the steady shift of production activities to the southern U.S. states and Mexico, despite considerable investments in traditional automotive manufacturing activities, including full participation in the bailout of GM and Chrysler in 2009 after the global financial crisis. In light of this, the Canadian government began to increase its public subsidies to promote R&D operations. A wide range of policy instruments have been employed in the past two decades by both the federal government and the provincial, or regional government, to increase the degree of R&D intensity among both OEMs and parts suppliers in the Ontario automotive sector. In UNIFOR's (the Canadian autoworkers union) most recent negotiations with the Big Three, it was production and R&D commitments, rather than wages, that were the primary focus (Lampinen 2016).

Government policies have relied on the use of direct subsidies to individual firms or partnerships and through competition bids, from which only the best projects are selected. Funds used to provide these incentives include the federal Automotive Innovation Fund, the federal Automotive Supplier Innovation Fund, the provincial Jobs and Prosperity Fund, Southwest and Eastern Ontario Development Funds, the Ontario's Business Growth Initiative, as well as funding from the Natural Sciences and Engineering Research Council.[3] A significant portion of the funding has been allocated to OEMs, who are reaching out to leading universities and beginning to establish their own research programs and partnerships in association with Ontario's post-secondary research institutions. Most recently, the federal government established the Next Generation Manufacturing (NGen) Supercluster, which offers smaller technology leaders like Clearpath Robotics and Myant an opportunity to co-create new mobility solutions with domestic Tier-1 automotive suppliers, such as Magna and Linamar. These initiatives provide financial incentives for OEMs to conduct R&D in the development of greener and more

[3] In a similar vein, automakers have also taken advantage of governments support for research and development through generous tax credits (Holmes et al., 2017).

fuel-efficient vehicles (Rutherford & Holmes, 2007; Holmes, Rutherford, & Carrey, 2017).

The AIF[4] was established in 2008 and was geared toward OEMs and first tier suppliers.[5] Funds have been allocated not just to build increased R&D capacity, but also to transfer the resulting technologies into new production capacity. For example, the fund has supported energy efficiency research by Toyota, as well as the implementation of new technologies in their existing production facilities, including new laser-welding robots to produce faster high-quality welds that enhance vehicle rigidity and, by extension, handling. Furthermore, automakers have partnered with various organizations in the Ontario innovation system through the **Automotive Partnership Canada** – which researches design-to-commercialization of electric vehicles – and the Partners for the Advancement of Collaborative Engineering Education (PACE) – which provides computer-based engineering tools to universities.[6]

Automotive-specific, company-led interventions have been accompanied by research funding programs to create incentives for the regional knowledge infrastructure to take up technological topics of importance to industry. National and provincial funding programs have been designed to encourage higher education institutions to collaborate with industry to help solve company specific problems. The federal government established Canada's Network of Centers of Excellence (NCE) program to close the gap between industry and academia and help in the commercialization of scientific research (Atkinson-Grosjean & Grosjean, 2000; Doern, Castle, & Phillips, 2016).[7] The capabilities of Ontario's knowledge infrastructure were enhanced significantly with the establishment of AUTO21 in 2000, a nationally funded NCE with $80 million in public funding and $60 million in private contributions, which sought to advance automotive research in pursuit of: health, safety and injury prevention; societal issues; materials and manufacturing; powertrains, fuels and emissions; design processes; and intelligent systems and sensors.

[4] Support for private sector investment in excess of $75 million.
[5] Set to last until 2021.
[6] PACE is geared towards educating and inspiring students to work collaboratively in a global setting.
[7] It also redirected public funds from basic to applied research for National Research Council Research (Doern et al., 2016).

Funding for research infrastructure also accelerated during the 2000s and was allocated through the Canadian Foundation for Innovation (CFI), and the federal government's Knowledge Infrastructure Program. For instance, the CFI and the matching Ontario Research Fund helped fund the Toyota $10-million Green and Intelligent Automotive (GAIA) research facility at the University of Waterloo Faculty of Engineering with $1-million initial funding from Toyota Motor Manufacturing Canada (TMMC) in 2015. At the provincial level, significant funds were allocated through the Jobs and Prosperity Fund established in 2015[8] and dedicated to establishing new production capacity (FCA minivan, Honda teaching plant, Mitsui high tech first facility for motor cores for EV and hybrids) as well as to establishing R&D capacity by FCA and Linamar (energy efficiency).[9]

Finally, R&D project funding can be allotted through newly established consortia of both industry and non-industry actors, including community colleges, universities, non-profits and industry. In 2016, government committed $10 million to the Canadian Urban Transit Research and Innovation Consortium, a centre to fund partnerships in support of R&D and the commercialization of technologies – such as light weighting and autonomous software – in partnership with the federal and Quebec governments (Shum 2016). The five identified research pillars within which CUTRIC-funded projects are classified are: 1) Low & Zero Emissions Vehicular and Infrastructure Innovation, 2) Lightweight Materials & Processes, 3) Autonomous Connected Vehicles, 4) Cyber- & Critical System Security, 5) Big Data & Analytics.

Policy analysis and next steps for OEMs and Tier 1 suppliers

Although the actions of policy makers, OEMs and universities has created the space room for increased industry-academic partnerships, collaboration remains a challenge. Individual projects are useful to companies, but they don't necessarily lead to long-term stable partnerships that continue past the end of funding. Our interviews with a number of OEMs suggest that they regarded programs such as AUTO21 as too academically focused and insufficiently driven by the of innovation needs of the industry. Other subsidiaries, however, are using the substantial

[8] Private investment must exceed $5 million for the project to be funded.
[9] https://news.ontario.ca/medg/en/2016/03/ontario-invests-in-new-electric-and-hybrid-vehicle-parts-manufacturing.html

increase in local university research capacity that resulted from the funding of the NCE to lobby their parent companies for additional R&D mandates in Ontario.

GM is expanding its R&D locations beyond the initial Canadian Regional Engineering Centre, also known as the Canadian Technical Centre, (located in Oshawa on the eastern edge of the Toronto region), which is responsible for vehicle design and development (particularly on chassis and sub-systems), research regarding product quality and manufacturing, as well as for 'connected car' and green technology research. Because the physical capacity of the CREC was insufficient to house the entirety of GM Canada's planned expansion, the company recently opened a new Automotive Software Development Centre in Markham, north of city and the traditional home to one of the region's major ICT clusters, to accommodate its new engineering hires. This expansion is intended to allow the Markham research centre to focus on autonomous vehicle technologies, vehicle safety, infotainment, and connected car technologies. The Automotive Software Development Centre opened late in the fall of 2016 and already has 120 engineers working in it. The Centre is also located close to IBM Canada's Software Lab in Markham, the largest software development laboratory in Canada, and IBM's third largest software lab with 2,500 employees responsible for developing some of IBM's middleware software. The location of the new Software Development Centre in Markham reflects the well-established strengths of that community in the software sector, but also suggests GM's intention to explore potential synergies between its existing OnStar technology and the burgeoning software capabilities at IBM and other local companies.

GM's expansion of its research facilities in Ontario is not limited to the new Automotive Software Development Centre in Markham. In October 2018, the company broke ground on the development of its new Toronto GM Mobility Campus, a 7-acre site at 721 Eastern Avenue, close to the Toronto waterfront and the proposed new development of the Quayside district as an innovative urban hub by Waterfront Toronto, the organization that manages the public lands on the waterfront for all three levels of government. The new Mobility Campus will be comprised of office space, research and development facilities, GM vehicle sales and service space, and a public experience area showcasing innovations in mobility, including electric and autonomous vehicles, e-bikes and car-sharing. Activities to be located at the Campus Campus will include: Urban Mobility Research and Development; the head offices and facilities for Maven Canada; a car dealership and service space for GM products; and public e-vehicle and e-bike charging station. When finished GM anticipates that the Campus will support between 150-265 high-paying skilled jobs, but that the employees will not be restricted to this site alone.[10] The company anticipates that there will be considerable movement of staff between the Markham Software Centre and the Toronto Mobility Centre depending on the projects they are working on.

GM Canada is continuing to lobby senior executives at the company's head office in Michigan to expand the amount of R&D being undertaken in Ontario, arguing that the high quality of software developers, Toronto's growing capacity in artificial intelligence and machine learning and the strength of the start-ecosystem in the Toronto-Waterloo Innovation Corridor, all make the region a prime location for the further expansion of its R&D activities for next generation mobility. The shift in focus on Ontario from a traditional production location to an advanced R&D location was further underlined in the November 2018 announcement that it was shuttering its production facilities in Oshawa, in operation since 1908, at the end of the current product mandate. The move was part of a broader corporate restructuring to shift resources out of the production of conventional sedans and into electric and autonomous vehicle programs over the next two years. In its defence of the plant shuttering, GM Canada said, "Our industry is transforming, and GM Canada is growing, hiring and leading the way in next generation automotive R&D, software and technology at our Technical Centre Campuses in Oshawa and Markham, our Cold Weather Testing Facility in Kapuskasing and with a new Urban Mobility Campus coming soon in Toronto. We are increasing our engineering base to 1,000 positions in Canada."[11]

While GM's transition has been the most dramatic among the three U.S.-based OEM's operating in Ontario, it has not been alone in ramping up its R&D activities in the jurisdiction. Ford Motor Company of Canada is also investing $590 million to set to establish a flexible engine assembly plant and expand an advanced Powertrain Research Center in Windsor, right across the river from Detroit and home to the majority of Ford's production facilities in Ontario. For its part, FCA is co-investing $18.2 million dollars with the federal regional development agency, FedDev Ontario, to make McMaster University's Automotive Research Centre in

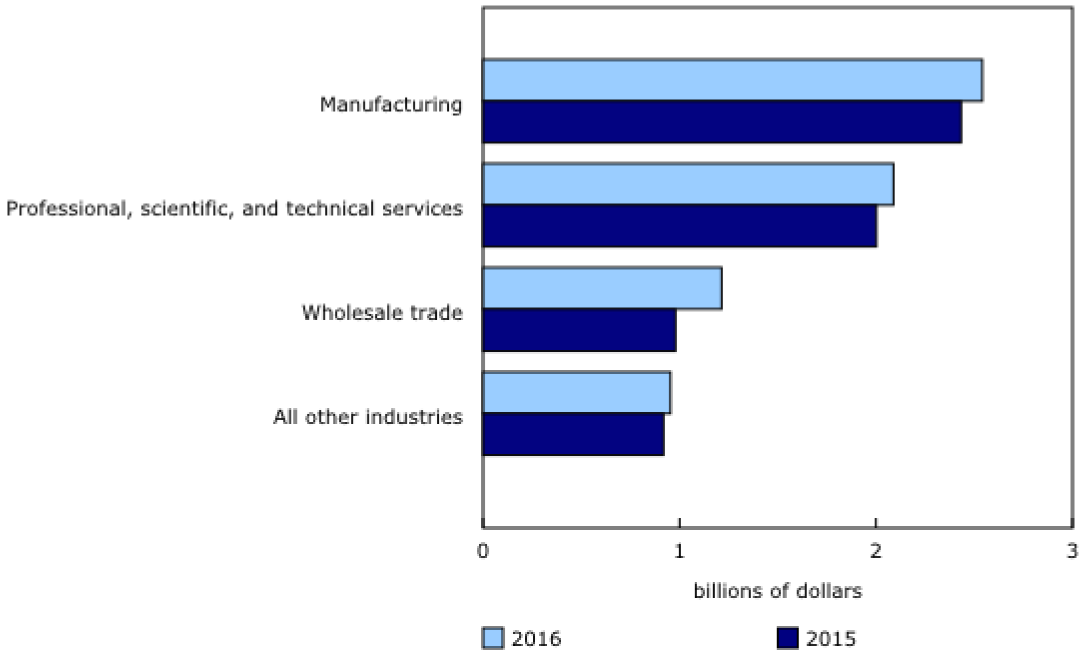
[10] http://721eastern.ca/about-the-project/
[11] https://www.supportingoshawaworkers.ca/site/ca/en/gm-transformation/home.html

Hamilton, Ontario, the centre for the development of its high-performance electric and hybrid powertrains.

Automotive innovation (at least the more disruptive kind) is not being generated by the OEMs alone. Our findings suggest the prospects for path hybridization in Southern Ontario are being strongly shaped by the presence of global and domestic IT/software companies. The Ottawa region, home of the former telecom giant, Nortel, has not traditionally been viewed as a core part of the province's automotive sector. However, the presence of QNX, a Blackberry subsidiary, has drawn considerable attention to the region. In December 2016, Blackberry announced the establishment of its BlackBerry QNX Autonomous Vehicle Innovation Centre (AVIC) in the Ottawa region to develop technology for connected and autonomous vehicles, both on its own and in collaboration with private and public sector organizations and research institutes. The new AVIC builds on QNX's 20-years of experience in developing and marketing the kernel that provides the platform for the infotainment systems found in a large number of vehicles on the market. The mandate of the centre is to foster new ideas and implement them through advanced engineering projects and vehicles demonstrations (Owram 2016).

Another notable new entrant into Ottawa's burgeoning automotive ecosystem is Apple, which recently leased 25,000 square feet of research space in Kanata, the home to Ottawa's telecom and ICT firms. Apple has clearly been drawn to the region by the presence of Blackberry QNX – indeed one of its first actions was to recruit Dan Doge, the founder of QNX to oversee its research facility – and is seeking to draw on existing regional strength in the ICT sector. Apple opening a significant research centre in the region has clearly put Ottawa on the map of locations relevant to connected vehicle development. Apple has dozens of software engineers in the Ottawa suburb of Kanata, many of whom came from QNX, working on the development of an operating system for automobiles, in others words the automotive OS (Gurman & De Vynck 2016). While Apple has provided limited information about the precise role that its Ottawa R&D centre is to play in its connected car and autonomous vehicle strategy, its growing presence in the region provides a further indication that Ontario's traditional strengths in the ICT sector constitute a strong inducement to shift the region's automotive sector onto a new developmental trajectory. The data presented in Figure 2 provides a preliminary indication of an increasing trend of R&D investment by foreign-owned affiliates in the manufacturing sector in Canada.

Figure 2: In-house research and development expenditures by foreign majority-owned affiliates, by major sector, 2015 and 2016



Data source: https://www150.statcan.gc.ca/n1/daily-quotidien/181114/dq181114a-eng.htm.

The degree to which growing linkages between foreign and domestic R&D facilities will impact the absorptive capabilities and strategies of local firms is unclear.[12] The section below outlines the initiatives to support suppliers and examines the extent to which they can help firms overcome institutional obstacles in the Canadian context.

Changes in the supply base

The Canadian automotive supplier industry has also experienced major changes in recent decades, including a movement toward the production of more electrical/electronic components. Globally, traditional electronics hardware component suppliers have gradually expanded their value chain coverage into ADAS/AD (Advanced Driver Assistance Systems and Automated Driving Features) component development and begun to present a competitive threat to incumbent automotive suppliers. The use of ICT in the supply chain has led to emergence of

[12] But efforts by GM indicate that they are interested in tapping into the Canadian supply chain.

new software companies supplying EV producers.[13] The Canadian economy is generally perceived to lack the kind of dense innovation networks and inter-company forms of collaboration that are characteristic of innovative regions in Europe and Japan (Smardon 2014).[14] Rutherford and Holmes (2007), however, refine this characterization, and highlight different degrees of collaboration depending on the industry sector (and/or sub-sector). Their work distinguishes between the core automotive parts sector and Windsor's tool, die, and mold (TDM) sector (2007), a core component of Ontario's automotive sector. They find evidence of a significant amount of informal knowledge flows between highly competitive TDM firms[15] through the movement of skilled workers and through social and family networks.[16] Waterloo, well known as one of the leading cities for ICT start-ups, is the home of a new network – Communitech's AUTO Peer2Peer Network, where ICT companies can share information about competing in the automotive segment.[17] The competitiveness of automotive-related SMEs is further enhanced by their willingness to collaborate with universities and community colleges [to the same degree as large companies] (Holmes, Rutherford and Carrey, 2017).

Waterloo's dynamic innovation ecosystem is increasingly attracting the attention of OEMs. There is evidence that GM is not only seeking to draw on research in academic institutions, but also to bring its own subsidiaries like Maven to Canada and to link key GM decision makers with innovative Canadian start-ups and SMEs. General Motors Canada joined the Communitech Corporate Innovation Hub in February 2016 with the opening of its "2908 Innovation Lab." It has been a regular participant in "Collision Days" at Communitech, the goal of which is to enable Canadian start-ups and SMEs to explore potential growth opportunities with OEMs and other established companies.

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[13] Companies that do manufacturing in Canada include: Etratech in Burlington, Vecture in Concord, which just got bought by Eberspacher (a big German Tier I). However, there are cases where companies produce and are moving R&D elsewhere, which might be due to difficulties they are facing with the supply chain (e.g. Electrovaya is getting government funds, but is manufacturing in Taiwan and planning to move R&D to Germany).

[14] The presence of innovation networks might suggest a greater ability to diffuse and uptake new knowledge.

[15] That have succeeded in adopting CAD/CAM technologies as part of their operations.

[16] But even well -connected firms struggle to protect their IP from OEMs.

[17] The presence of informal networks as a way to diffuse information might contribute to the capability of these firms to partake in the restructuring of the automotive sector in Ontario.

Government policies target the different types of suppliers relevant to the future of the automotive industry, including established automotive suppliers and new or potential entrants. Relevant companies range from 1) battery manufacturers, to 2) providers of connected vehicle technologies and 3) existing plastics molding firms, foundries, machine shops, tool and die manufacturers as well as electronic-component producers. Many of these initiatives are designed to help 1) new companies integrate into the automotive supply chain and 2) existing companies upgrade their technologies.

Public policy and the supply chain

Automotive supplier innovation programs – available to both individual firms and partnerships – are implemented by government and delivered through a range of intermediaries. The federal government allocates funding through the Automotive Supplier Innovation Program (ASIP, launched in 2015), while the Ontario Centers of Excellence and the APMA administer a number of competitive research grants, including the Connected Vehicle Automated Vehicle Program (CVAV, launched in 2014), the Automotive Supplier Competitiveness Program (ASCIP, launched in 2016) and AVIN (the Autonomous Vehicle Innovation Network). Finally, the existing regional development funds provide resources to upgrade equipment and train workers. In 2016, seven automotive companies in Windsor-Essex were awarded a combined funding share of $7.8 million. Most programs focus on the development of new technologies, and fewer on their diffusion across the supply base.

The ASIP is geared toward helping new entrants and existing suppliers with their R&D costs. Among new entrants, Pravala Car, which provides a connection management platform for connected vehicles, received $9.7 million, while Nano One received 1.9 million for the development of battery material production technology (CBC News 2016). Existing automotive suppliers have also received funding for the development of new production technologies (hot stamping, reducing measurement and inspection time) and products (plastic muffler).

Among the programs administered by the Ontario Centres of Excellence (OCE), AVIN (the Autonomous Vehicle Innovation Network) provides funding for the development and commercialization of transportation and infrastructure system technologies. Part of its task is to establish regional technology hubs where mobility companies can collaborate with Canadian universities on a variety of technical challenges. ASCIP ($5 million) is a smaller program but focuses on the diffusion of ICT technologies among existing automotive suppliers.[18] It is a partnership between the Automotive Parts Manufacturers Association (APMA)[19], OCE and the Province of Ontario's Ministry of Economic Development and Growth and was a part of the Business Growth Initiative (5-year, $400 million initiative).[20]

Policy analysis and next steps for the supply chain

Critics argue that the various federal and provincial programs are not synchronized or part of a comprehensive strategy to strengthen capabilities in key areas. They provide funding for R&D, but not project funding or support to bridge the gap between pilot projects and production at scale – i.e. crossing the "valley of death. SMEs face many difficulties gaining access to OEMs such as Ford and GM, especially in the absence of a working prototype of how different technologies would interrelate. CVAV's Connected Car program is among the rare initiatives that go beyond R&D and demonstrate the various challenges associated with integrating new technologies in end product vehicles.[21] It connected SMEs to each other and to large multinational and domestic companies in an effort to integrate existing vehicle technologies into functional prototypes. CVAV's Connected Car program brought together Ottawa-based QNX, universities[22] and a range of small companies. Despite its successes, the program demonstrated the challenges associated with the collaborative efforts necessary to bring technologies to life. There were issues with defining the obligations of the partners, communicating and learning about each other's strengths and weaknesses and equitably distributing resources through diligent budget documentation (Munim and Yates 2015). This suggests that there are further challenges to

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[18] http://www.oce-ontario.org/programs/commercialization-programs/automotive-supplier-competitiveness-improvement-program-ascip

[19] APMA's role is to market the initiative

[20] The program has two streams, including: 1) technology adoption of advanced hardware, software and training to enhance product life cycle management and improve competitiveness.

[21] There are some other examples where OCE funding helps join customers with suppliers, like in the case where Peytec and Ryerson are trying to bring the Internet of things to the factory floors of automotive OEMs (the total funds leveraged so far amount to $140,000 with $20,000 coming from OCE).

[22] The presence of a university in these projects is relevant because it opens access to funds from various resources including the OCE, NSERC, and other programs geared toward academic institutions.

be addressed along the supply chain in facilitating Ontario's transition into the emerging paradigm of connected, autonomous and electric vehicles.

Conclusion

Ontario's automotive industry has been undergoing a significant restructuring in terms of the region's policy orientation and the operations of both OEMs and suppliers, which has been strongly supported by a set of recent policies designed to incentivize increased R&D. Financial incentives to individual firms have supported OEM attempts to expand their Canadian R&D and production lines. On the other hand, competitive research funding has encouraged both OEMs and SMEs to partner with knowledge organizations, including universities and community colleges. Lastly, the emergent Canadian software landscape has attracted some of the biggest automotive software suppliers, which are tapping into its start-up landscape and establishing linkages with QNX. In light of this restructuring, the paper argues that the Ontario automotive sector is undergoing a process of *path* hybridization in a phase of transition toward being a regionally embedded sector with both global and local linkages. Future policy decision should consider all of these developments, instead of maintaining a limited focus on automakers.

Despite these advances, there are further challenges to this trajectory of path development for the Ontario automotive sector. The extent to which the major five OEMs operating in Ontario are dedicated to further expanding their R&D operations remains unclear and whether it will be sufficient to offset further employment reductions in automotive assembly which may be coming. Furthermore, there is considerable uncertainty surrounding the degree to which many of the new technologies can be commercialized in the Ontario context or translate into enhanced strengths in the supply chain.

Overall, although the interactions between firms and the regional knowledge landscape have intensified amid the evidence that OEMs are pursuing more of an asset augmenting strategy in Ontario, SMEs might not be able to overcome many of the institutional obstacles to scale up ranging from access to capital, trained labor and customers. Despite the fact that policies do not directly address the challenges facing many SMEs, the efforts by OEMs to tap into the start-up landscape, coupled with the resilience demonstrated by the automotive supply chain suggest that there is strong potential for the emergence of a new ecosystem of more innovative automotive companies in Ontario, capable of transforming the sector into a competitive jurisdiction in the 21st century automotive industry.

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