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GROWING AGRI-INNOVATION:

Investigating the barriers and drivers to the adoption of automation and robotics in Ontario's agriculture sector

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Photo courtesy Niagara Region

INTRODUCTION

This policy brief illuminates the opportunities and challenges associated with building competitive production systems in Ontario's agri-food sector, focusing on the issues farmers face in their adoption of automation and robotics technology. The brief is part of a more extensive study[1] to investigate the barriers to, and drivers of, innovation in pursuing globally competitive production systems in Ontario's agriculture sector. The research team conducted a survey in the early part of 2021, canvassing farms across Ontario on their adoption of innovative robotics and automation technology. Based on 171 responses, the findings were reported in our June 2021 Working Paper (Lemay, Boggs, & Conteh, 2021) and raised several questions in our efforts to better understand the underpinnings of technology adoption in the sector.

In this policy brief, we endeavour to answer some of those questions through a deeper dive into the survey and an analysis of 36 semi-structured interviews with agri-food stakeholders within the context of an agriculture innovation system.

The combined analyses of the survey and interviews challenge prevalent conceptions about the role of technology in building globally competitive production systems in Ontario's agriculture sector. The undercurrent of this argument is that technology adoption is highly contextual. Not only are there substantial differences in technology adoption between other industrial sectors (e.g., manufacturing) and agriculture, but there are also differences within the agriculture sector, itself. Adoption varies by kind of agricultural commodity, even within the distinctions of crops and livestock.

The analysis also pushes the envelope on conventional wisdom about the propensity of farmers to adopt automation and robotics technologies. Importantly, our findings challenge broad stereotypes about farmers being "slow adopters." The analysis unearths a far more complex and nuanced set of underlying strategic calculations that inform farmers' choices about the value of adopting automation and robotics technology. Our analysis suggests that competitiveness of a farm is not wholly dependent on the adoption of a specific innovation such as automation and robotics. In fact, there are instances where such adoption could reduce the competitiveness of a farm, if the decision is driven by external pressures that assume the benefits apply to all farms.

[1] *This is an Ontario Agri-food Research Initiative (OAFRI) project. OAFRI projects are funded through the Canadian Agricultural Partnership, a five-year, $3-billion commitment by Canada's federal, provincial, and territorial governments that supports Canada's agri-food and agri-products sectors.*

Our findings point to the need for re-considering how adoption of agri-innovations is supported and promoted. The issues we raise in this policy brief thus have significant public policy implications about our understanding of automation and robotics technology adoption and how government can help create the necessary conditions for farmers in Ontario to be more innovative and competitive.

The policy brief is organized as follows: First, we briefly review the existing literature shedding light on the role of regional agriculture innovation systems in shaping the adoption of technology. Second, we describe the survey and interview methods and data curation. Third, we re-cap the preliminary findings from the survey that were presented in the working paper. Fourth, combining cross-tabular analyses of the survey data and the thematic analysis of the interviews, we answer several questions that were posed for follow up in the working paper. With this analysis we bring to the fore deeper insights into the social, economic, and institutional factors and mechanisms that influence automation and robotics technology adoption by farmers in Ontario. Finally, based on these findings, we conclude with potential policy implications for government and other stakeholders. We also raise some questions that will inform and guide the project's subsequent phases.

The Case for Innovation

Global trends linked to complex societal imperatives such as sustainability, food security, changing consumer demands, and climate change, as well as the unprecedented pace of technological advances are fundamentally re-shaping the agri-food sector (Hall et al 2005; Fraser et al, 2016). To meet these challenges, there is increasing pressure on the agri-food sector to embrace technological innovation and, more specifically, the adoption of disruptive and transformative technologies that have been aggregated under the rubric of Industry 4.0, including automation and robotics (Oltra-Mestre et al 2020; Trivelli and Apicella 2019).

While many factors constrain farms from adopting technology, systemic barriers have been identified as priorities for policy intervention (OMAFRA 2020; Agri-food Economic Strategy Table 2017; AAFC 2011). Systemic barriers take several forms (AAFC 2011; Garbade et al 2012; Ntiamoah 2019). One such barrier is fragmented regional innovation systems (Herman et al 2015). Such systems are characterized by weak linkages and collaboration between and among key stakeholders, such as research centres, technology providers, educational institutions, advisory services, farmers, funding and investment organizations, and agricultural policy-makers within the same geographic space (The World Bank 2012).

Among other consequences, fragmented regional innovation systems result in weak supports for integrating technology across a region's agri-food value chain (OECD 2013). To compete in the global agri-food sector of the 21st century, farmers need to operate within a regional innovation system in cooperation with other agri-food innovation stakeholders, with a shared commitment to the creation and use of advanced technology (Hall et al 2005; Ramon 2016; Roucan-Kane 2011; Sabourin and Ayande 2015; Van Galen and Poppe 2013). **We believe there is a role for policy to ensure well-coordinated regional innovation systems that support the development and implementation of advanced agriculture technologies** (Cristóvão et al, 2012; Klerkx et al, 2012).

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METHODOLOGY

This policy brief draws on two datasets: an online survey distributed in four 'waves' from November 2020 to February 2021 that garnered responses from 171 Ontario farms (Figure 1—map), and findings from 36 semi-structured interviews conducted between July and September 2021. The survey focused on key questions about who has adopted what technologies and why or why not, as well as the barriers identified by both adopters and non-adopters. The detailed methodology and data curation for the survey is provided in the working paper.

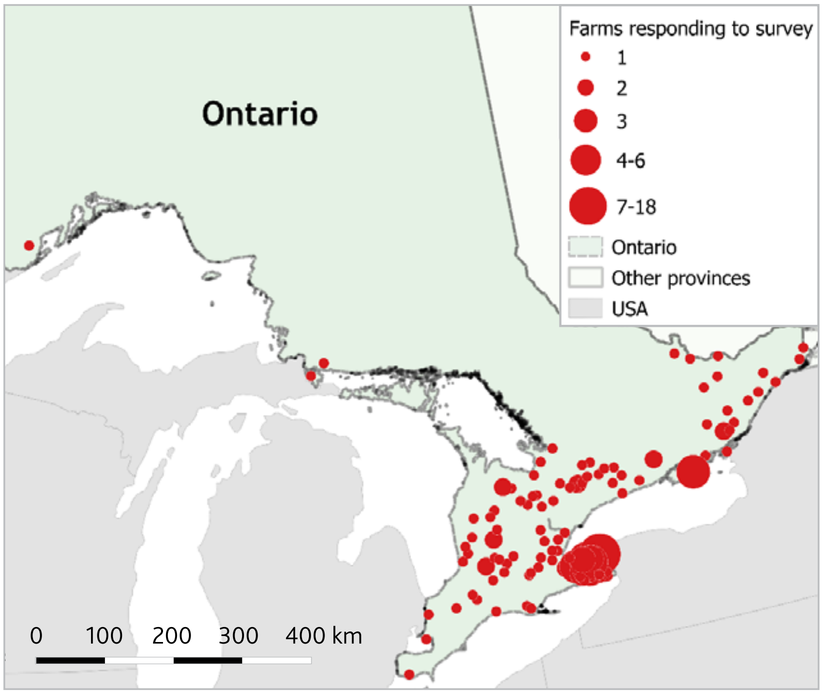
The survey results are used to understand 64 farmers' most successful experiences adopting automation and robotics technology. They also highlight why more than 100 farmers did not adopt. Given the exploratory and applied nature of our research, we relied on non-random sampling procedures. While our survey findings are not representative of a larger population, they do offer some novel insights that could be useful for informing policy decisions, as well as future studies.

Guided by agriculture innovation systems theory, the interviews were conducted with 16 farmers, four automation and robotics researchers, four technology solution developers and providers, and 12 intermediaries, including OMAFRA extension and production specialists, commodity organizations and other agriculture stakeholders. Both crop and livestock commodities are represented. Thirty of the 36 interviews were with individuals either based in, or serving, the Niagara region, which represents a case study of a regional agriculture innovation system.

A Re-cap of Preliminary Descriptive Survey Results

- The overall level of adoption of automation and robotics technology was 39 per cent, which is similar to other sectors. The survey also found crop producers (37 per cent) were *less likely* to have adopted robotics and automation technology innovations than livestock producers (44 per cent).
- The three most frequently adopted technologies were: automated machinery for seeding, spraying, fertilizing, and harvesting (50 per cent); tracking technologies such as RFID, GIS, and GPS (30 per cent); and automated process control sensors and systems (25 per cent).
- The top three reasons given for adopting automation and robotics were increased productivity (67 per cent), increased production efficiency (57 per cent), and reduced costs (56 per cent).
- The top three reasons given for not adopting technology were the high costs of acquisition (47 per cent), lack of relevant technology (35 per cent), and insufficient return on investment (34 per cent).
- The top three barriers experienced by adopters were insufficient return on investment (45 per cent), lack of government support or funding (36 per cent), and lack of in-house expertise (34 per cent).
- Adopters and non-adopters agreed that government should provide financial assistance and research grants for in-house development and promote established and proven technologies.

Figure 1. Distribution of responses based on postal code.



An online copy of our June 2021 Working Paper can be found here:
https://bit.ly/30u4wjP

Combining cross-tabular analyses of the survey data and the thematic analysis of the interviews, we address some questions that were raised by the survey results. We also present new insights derived from the interviews linked to our interest in understanding adoption and competitiveness within the context of an agricultural innovation system.

Off-the-Shelf Innovation, Performance & Local Suppliers

The survey found that farmers overwhelmingly purchased automation and robotics technology "off the shelf" in the local retail market (within 100 kilometres of the farm) rather than through leasing, in-house (co)development or licensing. When asked to choose between cost, ease of use, or performance as the key criteria in selecting a technology, 54 per cent of survey respondents chose performance.[2] We speculate that the propensity for farmers to acquire automation and robotics technologies off the shelf through local suppliers, and their preference for performance in choosing a technology, may be strategy for mitigating the risks associated with the adoption of advanced technology.

Further cross-tabular analysis of the survey data confirms a link between performance and purchasing technology from the retail market. For farms indicating performance as the most important criteria for selecting technology, it was more than twice as likely to be purchased off the shelf. For the farms that did not indicate performance was the most important criteria, the technology was about 1.5 times as likely to be purchased off the shelf.

Given that farmers have limited windows of opportunity to generate sufficient revenue to cover operational costs as well as a personal income, their preference for equipment that has proven performance is reasonable. Several interviewees pointed out that many automation and robotics technologies had yet to tangibly demonstrate promised benefits. This is also broadly consistent with Mitchell et al (2021: 413, 415), who find that 44 per cent of Ontario agri-retailers feel "the cost of precision agriculture technologies and services is greater than the benefit received."

The survey also showed a strong propensity for acquiring technology from local suppliers. Of the adopters who purchased *their most successful technology* off the shelf, nearly 70 per cent said they had purchased it from a supplier within 100 km. Technologies sold in the retail market through well-established distributors/suppliers are associated with proven and validated performance. When asked about purchasing technology from local, well-established suppliers, interviewees emphasized the importance of local, reliable access to service, parts and maintenance over the long term as a key factor in adoption decisions.

Challenges of international acquisition and the need for Canadian-made technology

A slightly different picture about technology acquisition emerged from the interviews than the survey. Virtually all automation and robotics technologies are imported from multinational manufacturers, who are headquartered either in the United States or Europe and may not have local distributors or suppliers. This raises several challenges for adoption. First, technologies are designed for specific production systems and practices, which are location and context based. This means that imported equipment often requires further validation and adaptation for Ontario production systems and conditions and even then, often does not achieve the performance claims made by the manufacturer. Furthermore, compliance with Canadian Standards Association standards is sometimes an issue with imported equipment.

Second, some but not all manufacturers sell through local distributors/retailers. In cases where there is no local distributor/retailer, teams must travel to Ontario to install and commission the equipment and provide training. Once the installation team leaves, timely technical service and maintenance is difficult. Even in cases where there is a local supplier, farmers still face delays in obtaining parts or access to technical support and maintenance for imported equipment.

Several interviewees highlighted the need for Canadian-made technology in order to overcome these challenges. However, there are challenges to developing Canadian-made technologies, such as the small domestic market which makes it difficult to build a viable business case or economies of scale. Given Canada's small market, perhaps support for validation, adaptation and ground-truthing of imported technologies, and building local technical capacity, would be an effective approach for supporting adoption.

[2] *While we did not define performance in the survey, it is understood to be a measure of functionality and utility. More simply, we assume that in choosing a technology based on performance, the expectation is that it will do a better job than what is currently being used to accomplish the same task.*

The Niagara Agriculture Innovation System

The survey results raised questions related to the dynamics of the Niagara agriculture innovation system, including the extent to which farmers are aware of and engage with local innovation resources, and how that engagement might be enhanced to create pathways for the adoption of automation and robotics technologies in Ontario's agriculture sector. The interviews shed light on some of the more salient relationships among stakeholders, including farmers, researchers, technology developers and intermediaries.

Overall, farmers in Niagara have weak connections to Niagara-based researchers and research facilities. Few of the farmers interviewed engaged or collaborated with Niagara-based research institutions. Those who had, were disappointed with the experience and felt that local research institutions were more focused on developing collaborations in larger markets. However, several farmers have developed long-term collaborations with international stakeholders for adoption of innovations other than automation and robotics, such as specialty crops.

Farmers have limited time, resources, or capacity to co-develop automation and robotics technologies with researchers and technology developers. Collaborating on technology development is an added risk in an already high-risk sector. Nonetheless, there have been some local automation and robotics development projects. One greenhouse operator, for example, has provided innovation space in their greenhouse for a local technology developer. They are collaborating on the development of new greenhouse automation equipment.

Weak connections between researchers, technology developers/solution providers and the agriculture sector were cited by several interviewees as a barrier to the widespread adoption of automation and robotics technology. Several interviewees described some A&R technologies as "solutions in search of a problem", meaning that the technologies being developed and promoted to farmers did not have value propositions that were compelling or addressed a problem that farmers consider a priority. Other interviewees highlighted the fact that while many researchers and technology developers were 'very good engineers', they lacked an understanding of the realities of farming, offering solutions that were not aligned with actual agricultural production practices.

There is growing support in Canada for ag-tech start-ups, which addresses an acknowledged need for Canadian-made agriculture technology that is designed for Canadian agriculture production models. However, interviewees expressed a reluctance to buy new technology from relatively new and unknown companies given the uncertain future of most start-ups and the need for reliable ongoing technical support, service and maintenance well into the future. To address farmers' concern about reliable technical support, it may be necessary for researchers and technology providers to build collaborations with more established, local farm equipment distributors/retailers to bring new technologies to market.

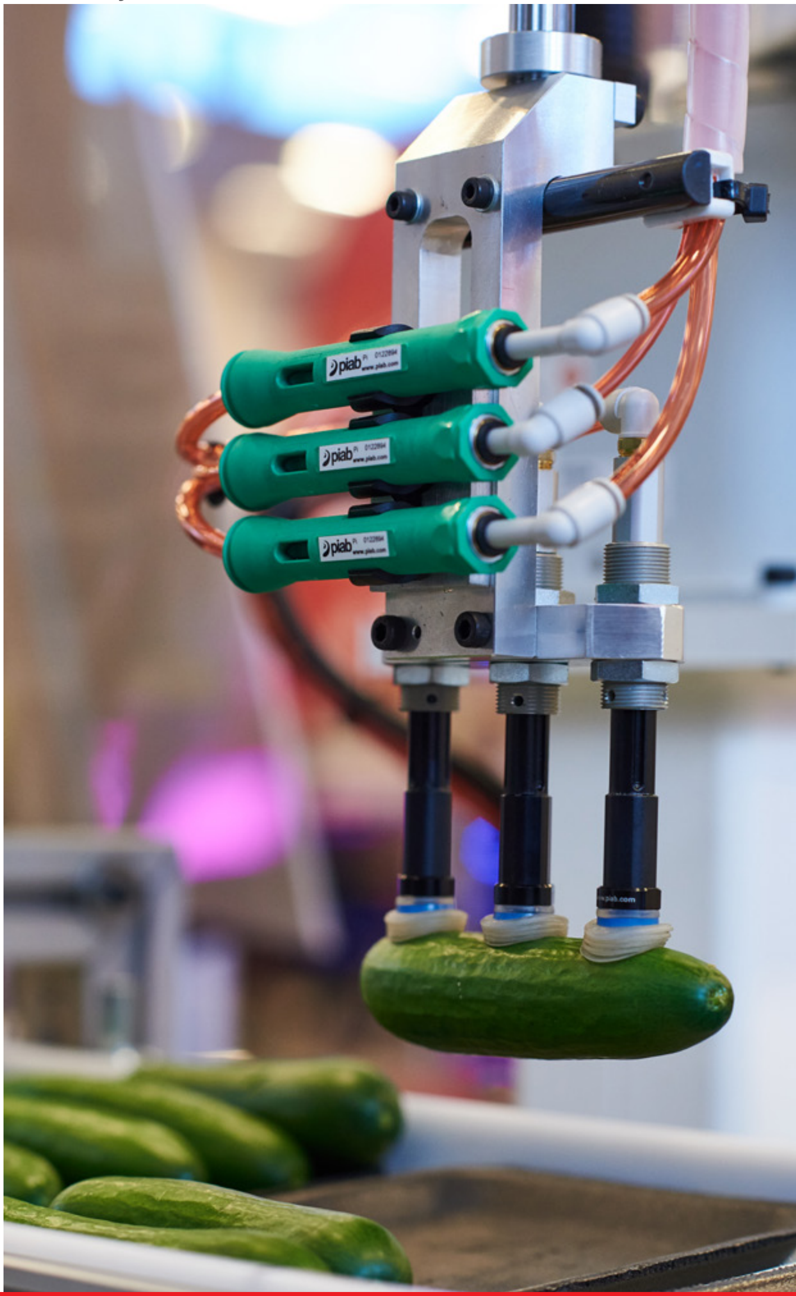
Several interviewees suggested that alternative business models could accelerate adoption. "Robots as a service" were proposed as an effective commercialization strategy that could build farmers' trust and confidence in the performance of robotics. This service-based model would allow farmers to 'see' the benefits of robotics without having to commit to purchasing. With that said, Mitchell et al (2018; 2021) report that precision agriculture service providers remain sceptical about whether the benefits of the service model are greater than the cost. Reading between the lines, Mitchell et al (2018; 2021) might caution us that adoption of service-based business models are also linked to consistent, demonstrated value.

Several of the individuals interviewed highlighted the potential agricultural applications of automation and robotics from other sectors (e.g., automotive, industrial manufacturing). However, others raised cautions related to the starkly different environments under which agriculture operates. Several interviewees pointed out that "we're not making widgets". This is a reference to the fact that, unlike industrial manufacturing, units of agriculture production (plants, animals) are highly diverse; they are not uniform or symmetrical in shape, size, colour, or spatial orientation. They do not develop at the same rate. Furthermore, farmers operate in less controllable environments, frequently at the mercy of climatic and biological forces beyond their control. This poses challenges for technologies such harvesting robots, which must be designed and trained to identify a range of similar, but not identical units in a more dynamic and varied production environment.

Advisory & Extension Services: A shifting landscape

Over the past 20 years, public advisory services have been significantly scaled back and a more pluralist system is emerging with an increase in advisory services being delivered by the private sector (Klerkx & Proctor 2013). When asked from whom they seek information and advice about adopting automation and robotics technologies, farmers generally said other farmers. This is consistent with recent literature showing that farmers are less trusting of traditional experts (e.g., agricultural researchers and extension specialists) and prefer advice and information from other farmers (Rust et al 2021) and independent agricultural consultants (Prokopy et al 2015; Stuart et al 2018). Several of the farmers interviewed were either unaware of advisory services provided by OMAFRA or chose not to access these services. Farmers also expressed a preference for one-on-one interactions. OMAFRA extension specialists and advisors highlighted the challenges of keeping up with the rapid advancements in automation and robotics technology and with making effective, meaningful connections with farmers. Similar findings about the challenges faced by public extension services have been reported (Prokopy et al 2015).

Photo courtesy Vineland Research



ROI: It's elusive and nebulous

From the survey, we learned that implementation of new automation and robotics technology and desired outcomes were achieved in less than two years. Most adopters reported it took less than one year to implement the technology (62 per cent) and more than half indicated they achieved outcomes in less than a year (56 per cent). Yet, adopters reported that insufficient return on investment (ROI) is the top barrier to adoption. How do farmers perceive ROI?

Through the interviews, we find that ROI is more than an objective calculation for farmers. There is an element of subjectivity to ROI that includes intangibles, such as quality of life, peace of mind, health and safety, and learning curves, which farmers use in 'calculating' ROI. This makes ROI somewhat nebulous and elusive. Moreover, robotics technologies tend to be task-specific, which means the equipment is used for a short time during the production cycle. Given the seasonal nature of much crop and livestock production, it is difficult to justify a major purchase of equipment that will be used for only a brief period of time. This is especially so when the alternative is to hire and train staff to do and rapidly switch between multiple tasks in a constantly changing work environment throughout the entire season or production cycle. Here, human versatility provides a superior substitute for automation and robotics in work environments requiring difficult-to-codify tasks, a point noted by Autor (2015). We speculate that adoption is linked to the duration of use. Technologies with a longer duration of use over the production cycle are more likely to be adopted.

Farm/Farmer Demographics and Adoption: No consensus

Farm and farmer demographics are a key factor of interest for understanding adoption decisions and behaviours. In our survey, farms which had adopted automation and robotics technology tended to be older and employ more workers than did non-adopter farms (Table 1). The average adopter farm is almost 15 years older and employs six more workers than the average non-adopting farm. The median adopter is 11 years older and reports one more employee than the median non-adopter.

Insights from the interviews highlight that newer farms have different decision criteria compared to more established farms. Newer farms tend to have more debt associated with the high investments needed to start a farm and therefore may not be in a financial position to invest in advanced technology until the farm is generating sufficient revenue to cover operating costs, debt re-payments, and income.

Table 1. Age and Size of Farm

	Adopters	Non-Adopters
Mean age (years)	46.1	30.6
Median age (years)	34.5	20
Mean size (# employees)	16	9.1
Median size (# employees)	4	3

In considering the implications of farm demographics (farm age and number of employees) on adoption decisions and behaviours, four caveats are in order. First, the survey is a non-random sample of farms and we cannot say that this finding is representative of the larger population of Ontario farms. Second, the stark differences we see in adoption among the commodities highlights the challenges of generalizing any findings across the agriculture sector. We were unable to usefully control for commodity type due to the small number of observations. Third, we collected no data on farm size (acreage) or annual revenue, which would create a better indicator for a farm's competitive position in the form of revenue per acre or a benchmarking measure. Finally, and more importantly, the literature on the relationship between farm/farmer demographics and adoption decisions is inconsistent (Carlisle, 2016; Knowler & Bradshaw, 2007; Yatribi, 2020). This raises a question of the value of demographic analyses for advancing our understanding of adoption.

Supply Management: Reduced risk, controlled conditions, high frequency of use leads to higher adoption

From the survey, we learned that the level of technology adoption by dairy farms is 73 per cent, which exceeds the overall provincial level of adoption (39 per cent) or even the level of adoption reported by respondents in the livestock sector (44 per cent). Dairy is a supply-managed commodity. Does the higher level of adoption reported by the dairy sector in our survey suggest that there is something about the supply management system that supports technology adoption? Some argue that supply management is a barrier to innovation. The findings of the survey, at the very least, cast doubt on this argument.

The interviews offer deeper insights into the relationship between supply management and adoption of automation and robotics technologies, which could tell us something about supply-managed commodities and innovation adoption more broadly defined. The interviews included all three supply-managed commodities: dairy, eggs, and chicken. In general, supply-managed commodities share three factors, which seem to be linked to higher levels of adoption, one of which is unique to supply management: enhanced risk mitigation, controlled production environments, and frequent use.

We speculate that these three factors act synergistically, rather than individually, in creating conditions that support higher levels of adoption than other commodities.

A unique characteristic of supply management is enhanced risk mitigation through stable pricing, well-defined costs of production, and regulated production levels. Financial projections are subject to less uncertainty, making it easier to make investments in innovative technology with a greater level of confidence in ROI than for non-supply-managed commodities.

Secondly, production models for supply-managed commodities are better suited for automation and robotics technologies. They operate in more stable and controllable environments. For example, both egg and chicken production operate in closed systems under specific environmental conditions for optimum production. Automation technologies, such as sensors and process controllers, provide continuous monitoring and adjustment of multiple parameters to maintain conditions within pre-set ranges. Robotic milking is also subject to close monitoring and controls. (As an aside, greenhouses, which operate in similar enclosed and controlled environments, also have higher levels of adoption of automation and robotics technologies.)

Third, supply-managed commodities operate year-round with multiple 'production cycles' in a year and the automation and robotics technologies most widely adopted have a high frequency of use. Environmental sensors and controllers in egg and chicken production operate continuously, while milking robots are used multiple times a day.

Data: How to manage, use and protect it

A common feature of automation and robotics technologies is the vast amount of data that is collected, which are purported to be invaluable for making production decisions that lead to various benefits. Through the interviews, several issues related to data were identified. First is data overload. Managing, analysing, and interpreting the massive volume of data is proving to be a challenge that limits the use of the data for production recommendations and decisions. Outsourcing data analysis to specialists was mentioned by several interviewees as a solution to making the data useful for production decisions. Other issues related to data that were raised during the interviews include privacy, security, ownership, interoperability, and integration. Similar findings about data have been reported previously (Mitchell et al 2018; 2021). It may be necessary to develop governance frameworks for addressing the risks associated with collecting, storing, and sharing large volumes of data.

Policy: Burdensome and misaligned

Many interviewees consider funding or cost-share programs that support adoption of automation and robotics as a disincentive to early adoption of the technology. Cost-share programs are generally reactive in nature, responding to an already established record of adoption. However, these funding or cost-share programs do not allow retroactive payments. This means that those "early adopters", farmers who adopted a technology before a cost-share program was launched, are not eligible for support. In a sense, funding and cost-share programs essentially support so-called 'laggards'— those who are late adopters—and disregards farmers who took the risk of pioneering a new technology. While this policy incentivizes the wider adoption of successful technologies, we speculate it discourages overall levels of adoption.

Other critiques of policies meant to support and promote the adoption of automation and robotics technology include the highly administrative and bureaucratic nature of funding and cost-share programs. Application and reporting requirements are overly burdensome. Many interviewees pointed out that programs often do not reflect the realities and diversity of agriculture. For instance, in some cases, new automation and robotics technologies require new barn designs. Automated robotic milking systems cannot be installed in conventional tie-stall barns. However, new barns are not an eligible expense in cost-shared programs that support the installation of robotic milking systems. Minimum levels of funding are often too high for smaller farms to consider and the competitive nature of the programs means that only a few farms receive support. Furthermore, timing of the programs is often misaligned with production cycles, making it difficult for farmers to find the time to prepare applications. Reflecting on these difficulties, one interviewee suggested that adoption "would not be policy-driven but would come from the bottom up."

Automation & Robotics: Not for everyone

Several interviewees raised concerns over the potential 'ripple effects' of automation and robotics technology, referring to the unintended impacts of adoption. The link between increased supply, lower prices and reduced margins was highlighted by several interviewees. Others pointed out that automation and robotics technology would not be a viable business decision for all farm operations. That some farmers choose not to adopt automation and robotic technologies should not be used as an indicator of their competitiveness. There are priorities and challenges that require other innovative solutions. Both the survey and interviews demonstrate that farmers are very open to adopting innovations that make sense for their operations, just not necessarily automation and robotics. The consensus from the interviews points to the need for support that is innovation agnostic.

CONCLUSION & NEXT STEPS

A summary of our findings suggests that widespread adoption of automation and robotics technologies by the agriculture sector is dependent on:

1. Technologies that provide solutions for real problems;
2. Technologies with proven/validated performance and benefits;
3. Equipment suppliers with reliable service, maintenance, and technical support;
4. Governance frameworks for data that protect privacy and security; and
5. Policies and programs that incentivize early adopters and smaller farms,

To conclude, this policy brief aimed to shed light on the opportunities and challenges associated with building a competitive production system in Ontario's agriculture sector, focusing on issues and constraints farmers face in their adoption of automation and robotics technology. Through a combination of surveys and interviews, we have provided a more nuanced portrait of the current barriers, constraints, drivers, and opportunities of automation and robotics technology adoption in southern Ontario's agri-food clusters. To date, our findings suggest that any failure on the part of farmers to adopt automation and robotics technologies is not because they are inherently 'slow adopters' due to their overly risk-averse or conservative nature. Rather, it is driven by what Vanclay (1992) called 'objectively rational' decisions.

In the case of automation and robotics, farmers are showing a reluctance to adopt technologies with unproven performance and profitability from suppliers with uncertain futures who have weak connections to, and understanding of, the agriculture sector.

With the findings reported in this policy brief, we plan to move on to identifying solutions for accelerating technology transfer and adoption in Ontario's agri-food sector. In addition to the survey and in-depth interviews, future studies will undertake focus group discussions bringing together agri-food stakeholders from industry, government, and academia to allow the research team to generate policy recommendations for evidence-based decision-making and program development. Future reports will also draw lessons from Canada's agri-food and advanced manufacturing "superclusters" to convey the links between innovative automation and robotics technology on the one hand and competitive production systems on the other. Our final report will strive to offer strong policy recommendations and concrete action steps to accelerate robotics and automation technology adoption by Ontario's agriculture sector. However, in doing so, we will also raise critical questions about how we should shift our thinking about the role of automation and robotics technology in advancing greater innovation and competitiveness in the agri-food sector, in particular primary production.

Photo courtesy Niagara Region

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The Niagara Community Observatory (NCO) at Brock University is a public-policy think-tank working in partnership with the Niagara community to foster, produce, and disseminate research on current and emerging local issues. More information on the NCO office, and an electronic copy of this report, can be found on its website www.brocku.ca/nco

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