

Digital challenges in agriculture and mining

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1. Key research question and major findings:

Theme 4 of the project challenged us to examine how the diffusion of digital technology across all sectors of the economy contributes to the overall dynamism and competitiveness of the Canadian economy. In that context, we were motivated to assess the rate of adoption of digitally enhanced approaches and to identify and assess any policy matters that affect Canada's ability to remain at the forefront of ICT development, adoption, diffusion and trade.

There is substantial effort globally to adapt and adopt digital technologies to the primary and secondary industries, particularly agriculture and mining, which are both diverse production systems, have large and complicated supply chains and are globally competitive. Some of the technological applications are purpose-built by and for actors in these sectors but many of the applications are being repurposed from other applications, often sourced from other countries (e.g. geomatics, GPS-coordinated mobility, sensors and distributed ledgers). Both sectors are global, but the dynamics and opportunities vary significantly.

The level of investment, especially in agriculture, has accelerated and is globally distributed. Venture capital and corporate investment in the agrifood tech industry totaled US\$37 billion over the past six years, a 29 percent year-over-year increase from 2012 to 2017, with a recent shift away from 'seed stage' deals towards late-stage investments, differentially outside continental US (in 2014 the US accounted for 90% of the global investment flow) (AgFunder, 2018). Canada ranks about third in the world in terms of activity in agriculture. In contrast, while global investments in mining are absolutely higher, and Canadian mining firms are marginally

more intensively investing in innovation than agriculture, relatively speaking Canadian mining lags Australia, where firms have invested more four times more in research and development than Canadian firms. This has led to a growing gap in research competitiveness and technology uptake over the last decade between Canada and Australia, the widely acknowledged global leader.

Canada is differentially adapting and adopting these technologies. Both sectors, while engaged with technological progress, are more inwardly focused, bringing in new technologies from abroad but not obviously sending many out to serve global markets. Most commercial farmers now use at least one and most use many digital applications. A recent Internet-based survey (Steel 2017) reported that 49% of farmers reported using precision agriculture tools on the entire farm and another 37% reported using it on part of the farm; only 11% had not tried using any of the tools. An average 63% of the acreage cultivated by the farmers surveyed was soil sampled, of which about 70% was tagged with GPS coordinates, which means about 40% of their total acreage was ready for intensive data capture and analysis. Almost all farmers surveyed (98%) used GPS guidance systems for their operations and 70% of chemical, 37% of fertilizer and 26% of seed applications used automatic section control. Almost 40% used remote imagery in-season to monitor their crops, 28% from satellite systems and 19% captured by drones. More than 85% of the combine harvesters used some form of real-time monitoring. About two-thirds of farmers reported using temperature and moisture sensors to monitor grain stored in bins. Farms report they share their data and its management with consultants/agronomists (31%), crop-input dealers (6%), equipment dealers (4%) and accountants (5%) (Phillips et al. 2016). None of this is obviously being directed by Canadian suppliers to serve foreign markets.

The digital opportunities in the mining and energy space vary by the type of extraction used. Drilling involves extensive geomatics and engineering physics, as directional drilling and fracking, leaching and various slurry techniques are used to extract ores from locked-in pockets in the overburden; while Canada is one of the leading innovators in this field, much of the focus currently is on oil extraction and not hard rock mining, most common in the Saskatchewan mining sector (HAL 2015). Long-wall mining, used in potash and uranium, involves a similar mix of geomatics and engineering, but mostly involves human-operated machinery, only some of which is being automated. Open-cut operations, often used for coal extraction and which account for half of the Alberta oil sands jobs, are perhaps the most amenable to automated machinery,

especially with autonomous vehicles, which make extraction cheaper, safer and more predictable; except in the far north for diamonds, this style of mining is primarily used for coal, which is in decline due to climate policies. A recent study concluded, and we verified independently, that the mining sector as a whole in Canada lags behind other sectors in uptake and use of digital innovations; over the life of the project we found some evidence of adoption of autonomous haul trucks, with the first Canadian trial in 2016; all of those machines are imported and none of the firms using the technology has identified any way to exploit their knowledge beyond their operations in Canada (Phillips and Wixted 2017).

We investigated a range of explanations for the differential engagement with digital innovations. Both sectors have a compelling need, Canada presents a large and open market for adoption and agriculture and mining for the most part are internationally focused, which all other things being equal should make domestic adoption and international diffusion more likely. At the firm level, mining reported fewer labour or capital barriers to adoption, and the policies and public programs were generally viewed as supportive of both sectors (except, somewhat puzzlingly by the experts who were actually delivering the programming) (Wixted and Jobe 2018). Yet adoption lags in mining in Canada and neither sector is much more than a receptor of technology through trade. The different industrial structure, investment cycles, scalability and trialability of the technologies are at least part of the explanation for differential adoption. In contrast to agriculture, which is highly competitive, most of the mining ventures were localized monopolies, often part of global oligopolies, which reduces the competitive pressures to innovate (Phillips and Wixted 2017). Similarly, investment in agriculture is amortized over 1-5 years while mining investment often has 25-40 year horizons, so that while innovations are imminently scalable and trialable in agriculture, mining has a harder time testing technologies in real time. The lack of external focus is not unique to the tech play in these sectors – with a few exceptions, Canadian firms tend to act locally rather than contest foreign markets. A Statistics Canada survey in 2011 revealed that only about 10% of small and medium sized firms exported, and only about 2% were intensively engaged in foreign trade (https://www.ic.gc.ca/eic/site/061.nsf/eng/h_02925.html#toc-04).

2. What do our findings mean for Canada's digital future?

We found somewhat counterintuitively that mining, which is well positioned to innovate does relatively little, while agriculture, which faces real barriers is aggressively engaged. While many observers jump to intellectual property strategies as a cause of changes, there is no evidence that Canada's system is either designed or operates in any ways that impede development. Firms, universities and governments have the full array of property tools (patents, copyrights, trademarks and trade secrets) that are appropriate to the sector and some success in exploiting them in these industries. Some suggest more needs to be done to encourage firms to exploit IP more aggressively, but there is no compelling evidence that this is an issue or that there is any explicit policy measure governments could use to change the outcomes. The only significant difference between the two sectors is the industrial structure—relatively stable and non-competitive conditions allow miners to delay adoption while the dynamics of the agricultural and food sector are driving forward investment and use. While agriculture is relatively less prepared for the IoT, is only a modest investor in research and faces significant technical barriers, the nature of the marketplace and production system has incentivized firms both inside and outside the industry to develop, adapt, adopt, finance and use the technology. In contrast, mining, which appears on the surface to be well prepared and face few technical barriers, is weakly involved in research and has exhibited little interest in adapting, adopting and using the technology in existing mining operations (Phillips and Wixted 2017).

We investigated the dynamic agrifood space more intensively. Starting in summer 2015 we attended trade shows and farm industry events to collect data. These annual events provided forums for local and global sellers to showcase, promote and market new products and services (Bathelt et al. 2014) helping to map what western Canadian entrepreneurs, global firms and others were offering farmers. From these introductory conversations, a series of relationships was established. Individuals from both entrepreneurial start-ups and major corporations were contacted for follow-up interviews. A total of 25 semi-structured interviews were conducted between June 2015 and August 2017 in order to understand the type of technology involved, their value proposition and their impression of the barriers and opportunities they faced in realizing their business strategies. From these field observations, interviews and Internet research, a typology describing the dynamism of the sector was selected as a structuring mechanism, including: formal top-down hierarchies versus bottom-up ad hoc groupings; and

closed, proprietary digital platforms with formal use-rules versus open and fully-interoperable systems. The resulting 2x2 typology offers four alternative pathways to development of a new smart farming world. In the first instance, we have found the top-down, closed corporate model (type I), advanced by multinationals like John Deere, is both not being directly developed in Canada and so far is not fully available for adaptation and adoption by Canadian farmers. This is likely to be a risk for any nation that is not currently home to one of the 16 or so anchor firms in the seeds, marketing or farm machinery sectors. Similarly, there was no evidence of any substantial open innovation but top-down networked activity in Canada (type II)—the open standards systems that are emerging and evolving in the US have little immediate connection to the opportunities and constraints of western Canadian farming. Again, the nature of first mover advantage and network effects may put many other nations in the same position of taking or leaving the platforms developed by others. In contrast, there is significant evidence of local investment, development, adaptation and adoption of the bottom-up efforts, both in the Type III hacking world and the Type IV primordial systems spaces. We found evidence of significant local bottom-up effort in research (Phillips et al. 2012), precision agriculture (e.g. AgSky) and big data (FarmLead), which suggests there is a base of capacity, albeit largely disconnected from global innovation networks. The most likely opportunity for Canadian farm machinery is in the digitization of peripherals, which is a good fit with the highly competitive niche short-line manufacturing sector centered in Saskatchewan. Most of those firms are aggressively testing how new sensor and control system can add value to their equipment. It is important to note that while a strategic play may emerge in any of the four quadrants, emerging entities may seek to exploit their early gains by adapting and adopting other strategies to either migrate to or colonize other quadrants. In that way, competitive pressures in the long run may drive out uniquely motivated actors from some quadrants.

Unlike in the platform spaces, so far there is no evidence that uniquely new market entrants can do much more than provide niche products and services, mostly in the interoperable space, which tends to lead to lower profits. The big transformative efforts are currently driven by large multinationals, none which are resident in or well situated in the western Canadian market. The mining sector is a good example of this. Australian based mining ventures currently dominate the global industry and have taken the lead in testing the new technology—Australian policy has been largely irrelevant to the story.

3. Key policy implications that flow from our findings

Some assert that our digital future is constrained by our access to labour and capital. We found no evidence that this is a real constraint in either sector, even though both operate in areas with thin labour markets, volatile revenues and often inadequate resources to direct to long-term research and development. The differential scale and durability of the fixed capital formation is likely more of a barrier, with mining the most locked-in and agriculture more dynamic. Unlike in the platform spaces of the digital system, consumers do not seem to have much influence yet on the rate and direction of digital innovation in either sector. We posit that agriculture can and in some instances may be reconfigured by new consumer led innovation, as they project their preferences upstream to the seed, input, farming and processing parts of the system. In contrast, we see more limited opportunities for consumers to help redefine the mining landscape. Undoubtedly social activism and related regulatory change will work to refine the social contract for resource development, but given the lumpiness of industrial investment it will be harder for niche markets to emerge and flourish.

Two immediate policy matters may determine how much Canada benefits from or is hollowed out by the digitization of the primary sector. First, the rules of engagement for data ownership and control are evolving as we speak. Some assert that control of data will uniquely drive the future of the industry. Private firms and industry associations are defining the rules of engagement. So far all of that effort is abroad. Phillips (2019) asserted that defining a Canadian policy for data will be vital to the future of the sector. The digitized farm offers the opportunity for greater precision and differentiation, which will generate value for both those who own the data and for those that use the data. Jobe (forthcoming) tested experimentally whether who owns the data matters. Coase hypothesized that ownership should have little or no effect on the market outcome, provided there is an efficient market. Others assert that individuals are prone to an endowment effect, whereby ownership imbues higher valuations. The larger the gap between valuations with and without ownership would impair optimal markets. Jobe found a statistically significant endowment effect among producers who see the market as zero- or negative sum, suggesting that early adopters may come from the group of market-savvy producers, with laggards either failing to engage or engaging too late to share in any early adopter premiums. The key concern about data is not that the aggregators can overly exploit and disadvantage the

producer individually, but more that system level data may enable aggregators to bet against any single market participant. In ag, this could involve Deere or some other aggregator that can see real time seeding or harvest data to hedge in the futures market in ways that exploit their insider knowledge; in mining it we are already seeing multinational companies make moves to refine their operations to exploit marginal cost pricing across all their operations globally, making real-time changes in production in their multiple units in different markets in response to changes in input prices, transportation costs, policy measures and capacity utilization. [BW1]

Finally, market structure matters. As a small market with significant regionalization, many of our markets have limited competition. Most of our grains-based agricultural and mining operations are globally focused, which one might think imposes competitive pressures on the enterprises. But the domestic structure, with intensive competition in grain farming but relatively isolated dairy farming (due to supply management) and mining ventures blunts the impact. Much of the effort that could and probably should be directed in dairy and mining to innovation is instead misdirected to negotiating rent-seeking agreements with local and national governments. A renewed focus on competition policy at the national level, including the opening up of markets through deregulation or trade liberalization might be ways to nudge complacent firms and sectors to engage more fully.

CDO Deliverables to March, 2019

Journal Articles

with Relf-Eckstein, J. Jobe. G. and Wixted, B. (Accepted). Configuring the new digital landscape in Western Canadian agriculture. *NJAS - Wageningen Journal of Life Sciences*. Special Edition. Social responses to ‘Smart Farming’: emerging (re)configurations of practices and institutions”.

with Relf-Eckstein, J. and Ballantyne, A. (submitted). Disruptive Transformation of the Agri-Ecosystem: Grassroots Solutions to Practical Problems using Smart Farming technologies. *NJAS - Wageningen Journal of Life Sciences*. Special Edition. Social responses to ‘Smart Farming’: emerging (re)configurations of practices and institutions”

Books and Book Chapters

With Awada, L. and Smyth, S. 2018. “The Adoption of Automated Phenotyping by Plant Breeders. In Intelligent Image Analysis for Plant Phenotyping” In *The Adoption of Automated Phenotyping by Plant Breeders*, eds. A. Samal, S. Das Choudhury, J.-G. Yu and J. Schnable. CRC Press/Taylor & Francis Group.

With Hertes, A. 2018. “Implementing the New Innovation Agenda” In *How Ottawa Spends*, eds K. Graham and A. Maslove. MQUP.

With Jobe, G., Das Gupta, A., Juma, S., Paul Trujillo Jacome,P., Kanyoro Karba, S., Rastogi, A., and Horvath, M. 2017. Science and innovation policy for Canada’s next 150 years. In *How Ottawa Spends. 2017-18: Canada@150*, K. Graham and A. Maslove (eds). McGill-Queens Press, 46-58.

Policy Papers and Reports

2018. “Are superclusters sensible policy?” JSGS Policy Brief, May 2018.

with Relf-Eckstein, J. and Ballantyne, A. 2018. “Disruptive Transformation of the Agri-Ecosystem: A Case Study of Bundled Emergent Technologies.” A project for Agriculture and Agri-Food Canada, Strategic Policy Branch. Contract 01B68-117-0245.

With Wixted, B. 2017. Differential adoption of digital technology in the western Canadian agriculture and mining sectors. CSIP Working Paper Series.

Theses

- Jobe., G. (forthcoming). MPP. Thesis tentatively titled “Valuing farm-level data in precision agriculture: A behavioural experiment testing for endowment effect.” MPP Thesis, JSGS, University of Saskatchewan.
- RElf-Eckstein, J. (forthcoming). MPP. Thesis tentatively titled: “Disruptive Transformation of the Agri-Ecosystem: Grassroots Solutions to Practical Problems using Smart Farming technologies.”. MPP Thesis, JSGS, University of Saskatchewan.

Conference papers and presentations

- Phillips, P. 2018. Digitizing and supersizing the western Canadian agri-food cluster. The Competitiveness Institute International Conference, Panel E2, Scaling collaborative networks for cluster growth in Canada. Toronto, October 18.
- with Jobe, G. 2018. “Agriculture’s ‘Off-Farm’ Data Revolution: A Behavioural Approach to Assessing Policy Implications.” Presentation at 5th Annual Creating Digital Opportunity Partnership Meeting. Vancouver, BC, 2018.
- With Lubieniechi, Simona; Bett, Kirstin; Bogdan, Ana-Maria; Chan, Crystal; Hertes, Aaron; Phillips, Andrew. 2018. Put Down the Pen, Pick up the Tablet: A Case Study on the Adoption of a Digital Data Collection System. Academic Poster at GIFS Annual Conference, Saskatoon, June.
- With Jobe, G. and Fotheringham, J. “Citizen Science in the Digital Age: Connecting Unmet Needs to Unapplied Capacities.” Presentation at 4th Annual Creating Digital Opportunity Partnership Meeting. Montréal, QC, 2017.
2017. The Global Digital Revolution and Canadian Agriculture. Keynote Address to the CAES Policy Conference on Agile Value Chains, Ottawa, January 13.
- With Wixted, B. 2017. Differential adoption of digital technology in the Canadian agriculture and mining sectors. Presentation at 4th Annual Creating Digital Opportunity Partnership Meeting. Montréal, QC.
- with Relf-Eckstein, J., Wixted, B., and Jobe. G. Digital opportunity in agriculture: Digitizing the western Canadian agricultural industry. Presentation at Annual General Meeting, SSHRC Partnership Grant on Creating Digital Opportunities. Saskatoon, SK. April 27, 2016.
- With Wixted, B. 2015. The Global Digital Revolution and Canadian Agriculture and Mining. Presentation at Annual General Meeting, SSHRC Partnership Grant on Creating Digital Opportunities. Ottawa, April 27.

Other Non-Academic Presentations

2018. “Configuring the new digital landscape in Western Canadian Agriculture.” Canadian Agricultural Policy Research Network Research Workshop, AAFC, Ottawa, October 11 & 12.

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Media

Phillips, P. 2019. Canadian agriculture is facing a digital challenge. *The Hill Times*, 20 March. Available at: <https://www.hilltimes.com/2019/03/20/canadian-agriculture-is-facing-a-digital-challenge/193157>

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