Adoption of digital and advanced technologies in Canada

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Introduction

Technology adoption has multiple benefits including productivity increase and higher quality of products, which in return can lead to increased economic and innovation performance. In a study conducted by Baldwin and Lin (2002), Canadian manufacturing firms reported improvement in productivity and product quality as the most important benefits to the adoption of technology. Using the 2014 edition of the Survey of Advanced Technology (SAT), we study the adoption patterns of Canadian firms and the impact of their technology adoption behavior on innovation propensity. In total, 7,912 firms from various sectors responded to the survey. Advanced and digital technologies are present in every sector of the Canadian economy. These technologies are divided into 5 main categories: Material Handling, Business Intelligence, Design, Smart manufacturing, and Green technologies[1]. Although during the course of this study we have studied all five families of technologies, this short summary focuses on advanced Business Intelligence (BI) technologies and advanced or Smart Manufacturing (SM) technologies.

1. Key research question and major findings

Firms choose the technologies to adopt to fulfil specific needs and achieve various goals. The ultimate research question that we aim to address is what is the impact of technology adoption on innovation. In doing so, we need to understand the current rate of technology adoption and the types of bundles that are adopted. The following table shows the adoption rate of each family of technologies in the survey, i.e. the proportion of firms from the sample that have adopted at least one technology of the five possible families:

Advanced technologies	Rate of adoption
Material Handling	44%
Business Intelligence (BI)	31%
Design	48%
Smart Manufacturing (SM) [Processing]	19%
Green	13%

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[1] The exact names of each families as specified in the survey are as follows: Advanced Material Handling, Supply Chain and Logistics Technologies; Advanced Business Intelligence Technologies; Advanced Design and Information Control Technologies; Advanced Processing and Fabrication Technologies; Advanced Green Technologies.

Considering that some of these technologies are specific to the sector of activity, we expect to find lower rates in advanced processing or Smart Manufacturing and Green technologies. Furthermore, some of the technologies in these last two families were also relatively new in 2014 and understandingly exhibit lower rates of adoption. In contrast, Business Intelligence technologies have been around for a while and are those that are common to all industries because every firm has data they can collect and use to take better business decisions.

In this short summary, we will only focus on the BI and SM families of technologies because they provide an interesting contrast and as such show the most striking results. Let us first list the different BI and SM technologies. We will refer to the letters in the following order in the rest of this summary:

Business intelligence:
   a. Executive dashboards for data analytics and decision making
   b. Software for large scale data processing (e.g. Hadoop)[2]
   c. Live-stream processing technology or real-time monitoring
   d. Software as a service (SaaS) and cloud computing software[1]
   e. Infrastructure as a service (IaaS) and cloud computing hardware[1]

Smart manufacturing:
   a. Flexible Manufacturing Cells or Systems
   b. Lasers used in material processing
   c. Robots with sensing or vision systems
   d. Robots without sensing or vision systems
   e. 4-9 axis computer numerically controlled machinery
   f. Additive manufacturing/3D printing for plastics
   g. Additive manufacturing/3D printing for metals
   h. Additive manufacturing/3D printing for other than plastics or metals
   i. Automated machinery for sorting, transporting or assembling parts
   j. Plasma sputtering
   k. Micro-manufacturing
   l. MEMS

Our methodology uses the the *apriori* algorithm to identify the patterns in technology adoption. We find that firms are adopting widely differing bundles of advanced technologies, thus justifying the market basket analysis using the *apriori* algorithm. This algorithm seeks the

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[2] IaaS regroups the entire infrastructure needed to run applications of software virtually or locally, such as networks, servers, etc. SaaS regroups the applications or software that are usually virtual. An example of this could be using Google Docs or Office 365 online, without needing to install the software on your machine locally. Finally, the real-time monitoring technologies requires IaaS and SaaS to be able to run locally or virtually based on the firm's needs.

most combinations of technologies and measures the probability of adopting a specific technology conditional of having adopted one or more other technologies.

Within the BI family, the most popular bundle of technologies is C-D-E with 13.5% of firms having adopted it. In the practical world, firms are using a lot of SaaS (D) and IaaS (E) mainly because usually one goes with the other. Many companies want to keep their data private and have their own hardware to run cloud applications. Real-time monitoring (C) on the other hand is a direct application of the last two technologies so it's not surprising to see them combined together. Furthermore, when C-E are adopted, there is an 89% chance that firms would also have adopted D. This also makes a lot of sense because as we mentioned, C is a software that is a direct application of D. In fact, if a firm already has the infrastructure (E) to run cloud computing (D), there is high probability that they will also cloud software such as real-time monitoring capabilities (C).

In terms of SM technologies, the adoption rate is much lower than BI technologies. We also find much fewer different bundles that are adopted. This could be attributed to the fact that SM technologies are more centered around the start of Industry 4.0, a term coined in Germany in 2012, and in 2014, we are only noticing the early adopters of these technologies. In addition, when we compare the firms that have adopted such technologies with those that plan to adopt them in the next 2 years, we see a stability over time for adoption within the BI family. In other words, whether firms had adopted or were planning to do so in the future, they were adopting the same bundles. In contrast, in the case of SM technologies, firms were adopting completely different bundles in the past compared to those they were planning to adopt in the future (post 2014). While 3D printing technologies had not been adopted by 2014, they were on the radar of these firms for the 2015-2016 period. The data collected by Statistics Canada in 2014 hence provides an outstanding opportunity to explore the very birth of some of the Industry 4.0 technologies.

Finally, our regression analysis has shown that the more technologies are adopted, the more firms are prone to introduce innovations[3]. In fact, the innovation propensity of a firm is directly linked to the number of technologies adopted. We also observe that most of the time, adopting a technology bundle is better for innovation success than adopting a single technology. While this is not news worthy, digging into which bundles of technologies have which impact on which type of innovation is highly relevant and remains to be done in the project.

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[3] Our regressions have considered product, process, marketing and commercialisation innovations, in addition to combinations of those: all types combined, technical versus non-technical innovations, as well as the new process innovation definition in the latest Olso manual combining process, marketing and commercialisation innovation into a single category.

In this regard, the methods used to map the patterns of technology adoption have pushed the boundaries of what Statistics Canada is used to in terms of data analysis. This new analytical process has required closed collaboration with the staff at CDER to ensure data protection while not compromising data analysis. This careful way of developing and testing new methods requires time, but the rewards, once the project finished will be commensurate.

2. Meaning for the Canadian digital opportunity

This research tells us that in 2014, i.e. near the start of the CDO Partnership, the uptake of such digital opportunities was somewhat low in terms of Business Intelligence technologies, and very low regarding Smart Manufacturing technologies. Our research has clearly shown that a wider adoption by firms has a direct impact on their innovation propensity. What remains to be done in this research project is to study the longer-term impact of such technology adoption (short and medium term).

The research findings with regards to the adoption of business intelligence technologies raise a few questions. First, the adoption rate of business intelligence technologies might seem low (31% of all firms surveyed have adopted at least one business intelligence technology), but we have not found any comparable benchmark in other countries. For instance, of those 31%, only 24% have adopted a big data processing software. Keeping in mind that the survey dates back to 2014, it is expected to have lower rates for this technology. In fact, today's most popular big data software (B) is Hadoop and it was introduced in 2011. In light of these numbers, we can say that some Canadian firms were amongst the early adopters of big data technologies. The characteristics of these early adopters have not yet been allowed to leave Statistics Canada, because our research is still in process and the results not yet finalized, and as such cannot be reported here.

However, it will be important to reexamine the adoption of these technologies in 2019, 5 years on, because nowadays, Internet of Things (IoT) and Artificial Intelligence (AI) taking are taking a more important place within the digital landscape, the adoption of BI technologies will be crucial for firms. Furthermore, we see the same trend with some SM technologies with less than 5% of firms having adopted a 3D printing bundle. We should indeed see an increase in the adoption rates of such technologies if a new detailed survey is released in the near future. This new survey would help develop further recommendations on public policies to support the digitalization of Canadian firms.

3. Key Policy implications for Canada

The study confirmed the low uptake of key digitally enabled technologies, specifically the BI and SM technology families, which include "big data" and 3D printing technologies; and showed that adopting digital technologies might be a complex process as firms must usually adopt not only one technology but a bundle of technologies. We argue that it is a low rate because we expect most firms to have adopted some sort of big data technologies. In the era of ERPs, adopting a new technology was a pass or fail process. In today's Industry 4.0 world, the process of adopting advanced BI or SM technologies is more complex because not only is it important to select the right bundle of technologies, but it becomes even more crucial to implement them in the correct order. In fact, the consequences of a "failed" implementation could take years to manifest itself, and would be very difficult to pin point to a specific technology or to a specific order. Firms will pick and choose among a vast number of technologies which will render a one size fits all innovation support policy extremely difficult to implement and to some extent be undesirable. The question as to how to best support firm in their innovation process which is highly intertwined with the technologies that they will select or develop as underlying process innovation, is becoming increasingly complex and command a drastic change in the way we design these new "adapted" innovation policies. Some potential policy implications combining these two results are:

Managerial and non-managerial Talent: Digitally transformative technologies (such as use of big data/machine learning technologies) have the potential to change the firm's core business model. This entails a complex and highly strategic process where C-Suite executives need to be involved to develop the right strategy and selecting the right portfolio of technologies. Adopting these transformative technologies might also entail reflecting on the right mix of skills within the firm, proper training for internal employees and possibility the recruitment of additional expertise. In fact, firms need to find the right balance between hiring expensive external consultants and developing their internal talent as well.

Capital/investment: The optimal suite of technologies to adopt in order to be competitive in a global market (where local market tends to disappear with digital technology/platform-based economy) might be prohibitive for some firms. As mentioned above, technology adoption in some cases might involve larger changes within the firm (organizational innovation, change in mix of workers/training). Smaller or younger firms might not have the resources (financial, managerial experience) to undertake all the needed changes to be truly competitive. A case should be made as per whether there is a market or systemic failure that would need government intervention or not. It should also be mentioned that the superclusters might have a role to play in facilitating to the adoption of these advanced technologies.