The adoption patterns of advanced and digital technologies in Canada

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Background and context

Technology adoption has multiple benefits including productivity increase and higher quality of products, which in return can lead to increased economic performance. The industry 4.0 revolution is made possible by the advances in ICT technologies allowing the integration of technologies such as cloud-computing and IoT which leads to smart-manufacturing (SM). This paper aims at understanding the adoption patterns of advanced technologies by Canadian firms. In total, we explore four main families of technologies (manual handling, business intelligence, processing, and design) across different sectors.

Literature review

In manufacturing, technology is defined as the set of tools (automation and integration) used in the different stages of design, manufacturing, planning and control of the product (Ettlie and Reifeis, 1987). According to Bello-Pintado et al. (2018), this idea of complementary set of technologies may have an effect on firm performance. In fact, the specific combination of a set of SM technologies in a firm can makes it difficult to be transferable by another firm and thus, provides a competitive advantage (Milgrom and Roberts, 1995, Stoneman and Kwon, 1994).

The adoption of advanced business intelligence technologies – often ICT driven is an important way for firms to become more productive. These technologies are key enablers for SM and it can be argued that it increases a firm's propensity to innovate. As described by Bantau and Rayburn (2016), the first and second wave of ICT were used to automate individual activities and increase connectivity respectively. Today, advanced technologies that are often ICT-driven have become part of complex products and play a key role in productivity improvement (Breur, 2015, Porter and Heppelmann, 2014). Advanced software and connectivity provides new data and a potential competitive advantage to organizations able to make use of it (Porter and Heppelmann, 2015).

Currently, there is a gap in the literature with regards to the optimal bundle of technologies to be adopted. Our research is focused on the local context of advanced technologies in Canadian firms. The key research question we are trying to address is to understand the adoption patterns of these technologies.

Methodology

Our paper uses the apriori algorithm, which looks for patterns in technology adoption. We focus on a market basket analysis approach to understand what bundles of technologies are being adopted by Canadian firms. We look for popular set of technologies but also for sets that are less known and perhaps more used by early adopters. Our data comes from the 2014 edition of the Survey of Advanced Technology (SAT) provided by Statistics Canada. In total, we have 7912 firms who responded to the survey with their technology adoption strategies. These firms come from different industries including the manufacturing sector.

Results

In the processing and design families, the most popular set of technologies adopted are (a) Extranet and EDI and (b) Wireless communications for production. This bundle of technologies has been adopted by 22% of firms. Furthermore, when a firm has adopted (b) there is a 61% probability that it will also have adopted (a). A less popular bundle integrated (c) CAE, CAM, Virtual Product development, (d) Virtual manufacturing, and (e) Enterprise Resource Planning (ERP). In fact, only 5.3% of firms adopted it. However, this set seemed to be very complementary for firms because they are almost always adopted together. In fact, if (d) and (e) are adopted, there is a 90% probability that (c) would be adopted as well. This makes a lot of sense because it is a set of technologies that is complementary. ERP will complement virtual product development and production. When we look at additive manufacturing, only 5 % of firms adopted 3D printing. If 3D printing for metals was adopted, there is a 75% 3D printing for plastics was also adopted. This particular set of technologies is isolated from the rest, suggesting that only early adopters have been experimenting with additive manufacturing.

Our results also expected to show that some BI technologies are at the core of every industry and are used in complementarity with the other families of technologies. Before we dive-in into the business intelligence family, we need to explain the different BI technologies. We will refer to the letters A-B-C-D-E in the following order:

a. Executive dashboards for data analytics and decision making
b. Software for large scale data processing (e.g. Hadoop)[1]
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]

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 a 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). The other results that we find is that 5% companies are adopting all of these technologies together, which could mean that only companies with high capital can afford them. When technologies (a)-(b)-(c) and (e) or (d) are adopted together, there is respectively a 98% to have adopted (d) and 81% to have adopted E. The key fact here is that the more technologies firms adopt, the higher the chances of having SaaS (d) and or IaaS (e) together. Consequently, the more technologies adopted, the more infrastructure and cloud-computing capabilities become essential.

[1] 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.

Conclusion

The study confirmed the low uptake of key advanced manufacturing and business intelligence technologies, specifically the additive manufacturing and big-data technologies which are a key application of smart-manufacturing. The study also showed that adopting advanced technologies might be a complex process as firms usually, must adopt not only one technology, but a bundle of technologies. In the era of ERPs, adopting a new technology was a pass or fail. In today's 4.0 world, the process of adopting advanced technologies is more complex because but it becomes even more crucial to implement them in the correct order. Some potential policy implications combining these two results include external and internal talent management as well as a capital investment strategy to ensure the right technologies are adopted at the right time.