CANADIAN PRODUCTIVITY, SECULAR STAGNATION, AND TECHNOLOGICAL

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INTRODUCTION

Since the early 2000s Canada's productivity growth has been poor relative to historical and international levels. While there is no general agreement about the causes of this slowdown, there is some concern among a number of prominent economists that it may presage the beginning of an extended period of secular stagnation.[1] Despite this lack of consensus, many contend that technological change, which, for the last 150 or so years, through good times and bad, had been a main source of productivity advances and output growth is no longer up to the task. Gordon (2015), among others, maintains that the great inventions and innovations of the second industrial revolution - electricity, the internal combustion engine, organic chemicals - are spent forces and nothing evenly remotely comparable to their transformative impact, with the possible exception of the ICT revolution, also over, is conceivable for the foreseeable future. From this point of view, then, lackluster technical change has been a major contributor to the recent fall off in productivity growth – and there is little reason to believe that a turnaround is imminent.

[1] See, e.g., Gordon (2012, 2015), Summers (2015), Fernald et al (2016).

Their hypothesis raises two fundamental questions about growth and productivity in Canada. First, can the post-2000 slowdown in Canadian productivity growth be attributed, at least in part, to a falloff in the pace of technical change? The answer, as we show, is, by and large, yes. The second, which flows directly from the first, is the following. Can we infer from the marked drop in innovative activity in the first decade or so of the new century that Canada, along with other developed economies, faces a dismal future of modest (at best) technological advances and, therefore, very low levels of productivity and economic growth? Although the answer to this question is less definitive for Canada than it is for the US, we show there are tentative indications even here that the pace of technological change has begun to rebound and is likely to accelerate, not moderate, in the next few years. From this perspective, then, the answer is no. If we are correct, the issues that Canada must deal with are not those linked to slow productivity growth and secular stagnation but are, instead, problems thrown up by the new technologies. Specifically, the new technologies, many of which are related to AI and robotics, will impact employment opportunities, skills requirements, and, potentially, income distributions.

We proceed as follows in the paper. In the next section, we review the evidence on the recent slump in productivity in Canada and display recent trends in the multifactor productivity (MFP) of the goods and service producing sectors. In the following section, building on our past work, we present measures of innovative activity derived from books held in Canadian libraries in the different fields of technology (based on an analysis of OCLC holdings and WorldCat data). These book-based measures indicate that the fall off in innovative activity closely parallels the productivity decline both in terms of timing and in terms of areas of economic activity. In short, the data show a drop in technological advances beginning for the most part in the early

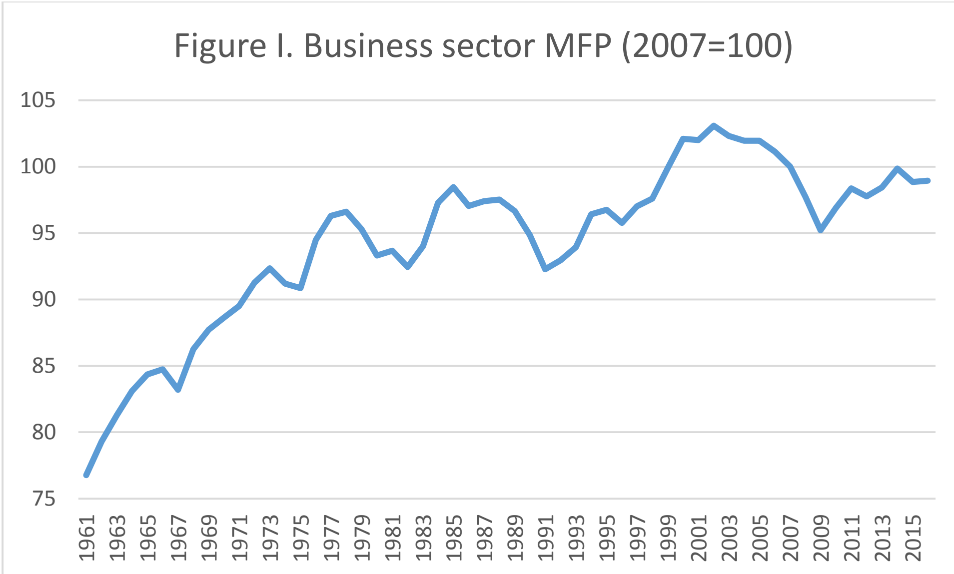
2000s, centered primarily (but not exclusively) in electronics and goods producing technologies. In section four, we estimate a series of VARs to determine the relationship between the indicators and MFP measures, and examine how much of the slowdown can be attributed to the slowdown in technical change. We find, first, there is a positive relationship between our aggregate technology measures and business sector MFP. Second, we find that innovations related to electrical goods (including computer networks and telecommunications) as well as those related to mechanical machinery have a significant positive impact on productivity, and have been the most important drivers of Canadian MFP.

In section five, we review evidence on the current pace of technical change. First, we present some indicators based on computer and technical titles available for sale at Amazon.com and Amazon.ca. These data show that there are tentative signs of a rebound in technical change (more marked at present in the US than in Canada). Next, through textual analysis of book data and other printed sources, we pinpoint the specific areas – AI, robotics, etc. – where the resurgence is taking place. Given that these innovations are in the areas we find are main drivers of Canadian productivity, provided that Canada adopts the new technologies, we should see begin to see a recovery in productivity and a substantial improvement in the economy's growth prospects. Section six offers some concluding remarks.

II. The Great "Moderation" in MFP Growth

While Canada has witnessed a number of productivity slowdowns, the one that we focus on here is the recent slowdown. As the data from Statistics Canada in Figure I demonstrates, appears to date from the early 2000s.[2]

[2] MPF data was retrieved from http://www5.statcan.gc.ca/cansim/a26?lang=eng&id=3830021.



As in other notable periods of slowdown (e.g., mid-1970s and 1930s when the original concern about secular stagnation was raised), a number of countries around the world have experienced a similar fall off in productivity growth around the same time. In the US, for example, as can be seen in Table 1, both total factor productivity (TFP) corrected for utilization and average growth rates have dropped off in more recent years with significant declines noticeable starting the early o mid-2000s.[3]

Table I. Potential Slowdown in productivity growth?

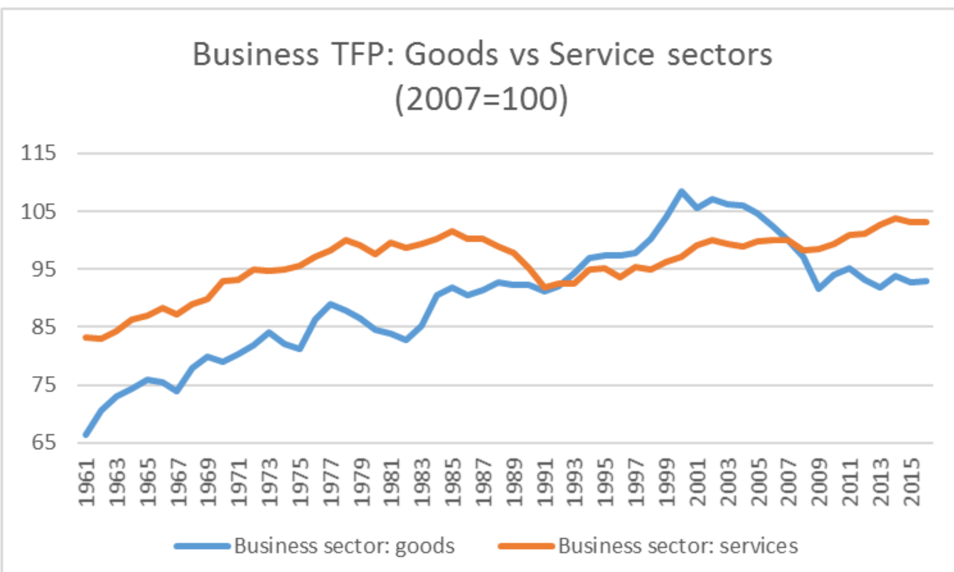
	Avg. TFP growth	Avg. growth (Fernald)
Post war mean	1.26	1.30
Since 1995:4	1.05	1.09
Since 2001:1	0.77	0.77
Past 8 qtrs	0.65	0.61
Past 4 qtrs	0.04	0.21

Source: J. Fernald (2016)

[3] See Table 3 in http://www.statcan.gc.ca/pub/15-206-x/2013031/t003-eng.htm for additional US-Canada comparisons showing a slowdown at the end of the 20th century in productivity for both countries.

Not all sectors have been equally affected. [4] The disaggregated Canadian data indicate that the that the largest contributors to the decline in business sector MFP were the goods producing industries such as mining and quarrying, utilities, manufacturing, construction, agriculture, fishing and forestry where, after 2002, MFP actually fell in absolute terms.[5] In contrast, as can be observed in Figure II, the service sectors - Wholesale and Retail Trade, Transportation, Information, Finance and Insurance, Real estate, Education, Health Care, Arts and Entertainment, Recreation and Tourism, Public Administration and other services - suffered an absolute fall off in MFP in the 1980s, but has, since then, experienced modest year over year increases.

Figure II. MFP by Sector



[4] See Gu and Lee (2013) for additional evidence on the variation in sectoral MFP growth rates.
[5] Statistics Canada's definition of goods producing industries is found here: http://www23.statcan.gc.ca/imdb/p3VD.pl?Function=getVD&TVD=138253&CVD=138254&CPV=11-33&CST=01012012&CLV=1&MLV=6&D=1

The key question: did a decline in the pace of innovative activity in Canada (and elsewhere), as Gordon (2015) argue, contribute to the drop in productivity growth?

III. A Great "Moderation" in Technical Change?

According to the technological pessimists, the second industrial revolution ushered in an stunning array of new technologies – electricity, the internal combustion engine, clean water and effective sewer systems - that dramatically changed the way Americans lived and worked.[6] By the 1960s, however, the economic stimulus provided by these advances was, for the most part, over and those that followed typically lacked the transformative force of their predecessors. The one exception may have been computer and information technologies (the so-called "Third Industrial Revolution"). Although, Gordon (2015) and others argue their impact on output and productivity, while substantial, was relatively brief.

This view may have some merit. It is widely accepted that innovations in information technology (IT) were largely responsible for productivity growth in the last years of the 20th century. However, there is some evidence to suggest that advances in a number of IT areas has slowed. Computers are today often viewed more as commodities than as technological *wunderkinder* and some argue Moore's Law (i.e., the doubling of transistors and related computing power per circuit every two years) be less of a law than we thought (See Figure III).

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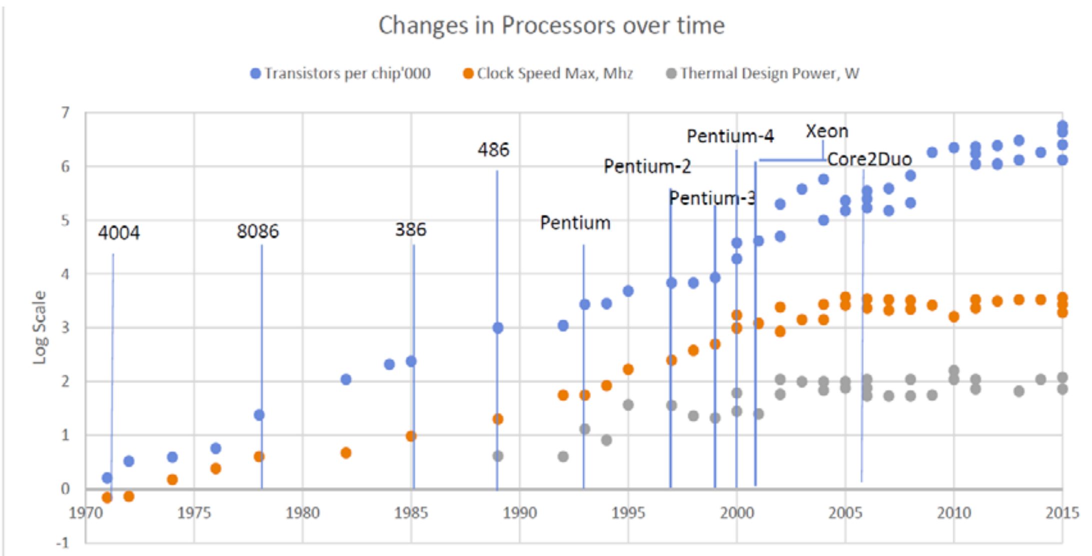
[6] It is worth pointing out that these urban public health initiatives were not in themselves technological advances. The real advances were associated with the germ theory of disease (see Mokyr (1990, 2002)) and other breakthroughs in medicine and biology.

That said, given that previous Industrial revolutions took over 100 years to play out, with ebbs and flows in innovations associated with them, one ebb in IT innovation may not warrant the writing of the third industrial revolution's obituary yet. [7] Indeed, as we will see below, while there may have been a slowdown, our metrics suggest that AI and robotic technologies, appear to at the beginning of their diffusion cycle.

Figure III.



Notes: Vertical lines show date of chip introduction. Thermal design power series is based on the maximum safe power consumption levels. Source of data: http://www.economist.com/technology-quarterly/2016-03-12/after-moores-law, based on information from the Economist, Intel, Linley group, IB consulting, and Bob Colwell.

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[4] For example, recent articles stemming from statements and research from the computer industry have suggested that Moore's Law many not be dead. The conclusions are based on the fact that, as it is traditionally defined, Moore's Law is not the correct way to measure the advances currently. See e.g., http://www.telegraph.co.uk/technology/2017/01/05/ces-2017-moores-law-not-dead-says-intel-boss/ , https://newsroom.intel.com/editorials/moores-law-setting-the-record-straight/ and https://venturebeat.com/2017/04/01/analyst-intels-latest-disclosure-shows-moores-law-isnt-slowing/

III. 1. Quantifying Technical Change

We use in this paper, as we have elsewhere, book-based measures of technical change.[8] The idea behind our measures is very simple and highly intuitive. Books will be written and published on new technologies because writers can make money by spreading the word and educating others about the innovations, and publishers, in turn, profit from selling the titles. Timing of the publications, of course, is critical – too early to market and there is no demand, too late, and demand is already fulfilled by competitors. As a result, the first appearance of titles on a new technology typically coincide with the commercialization/adoption date of the innovation, and, therefore, tracking the changes in the number of titles over time provides a concrete measure of changes in technology.

Book-based measures have other attractive properties. They are available at least on an annual basis over a long time horizon, and they are objective in that their classification is determined by specialists in the field (librarians, publishers and/or booksellers). They also weight technologies according to their importance since the number of titles, by and large, vary according to the perceived significance of the innovation and the size of market for it. [9] And finally, they are more likely than other indicators to cover the full range of both product and process innovations because all will be of interest to readers and potential adopters.

These measures also overcome many of the shortcomings associated with using more traditional indicators of technical change such as cleansed residuals, patent counts, and R&D expenditures when attempting to track commercialized technologies. The problem with the first

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[8]See, Alexopoulos (2011); Alexopoulos and Cohen (2011).
[9] The weighting, in essence, occurs since publishers make well-informed forecasts about the size of market for the technology and thus the potential demand for related titles. The larger and more important the technology, *ceteris paribus*, the more titles will be released.

of these is that while changes in productivity (MFP or labour) are frequently associated with technical change, they can also be driven by factors that are totally unrelated to new technologies.[10] As for patents (counts and/or citations), while the provide some indication as to what might come to market, many patents do not result in commercially viable innovations and even for those that do, the lag between the patent date and the diffusion of the technology varies widely and unpredictably, thus making it difficult to link the innovation to changes in productivity. R&D expenditures, which typically predate patents, are plagued by similar problems if one wants to gain insight into the timing and commercialization of new technologies.

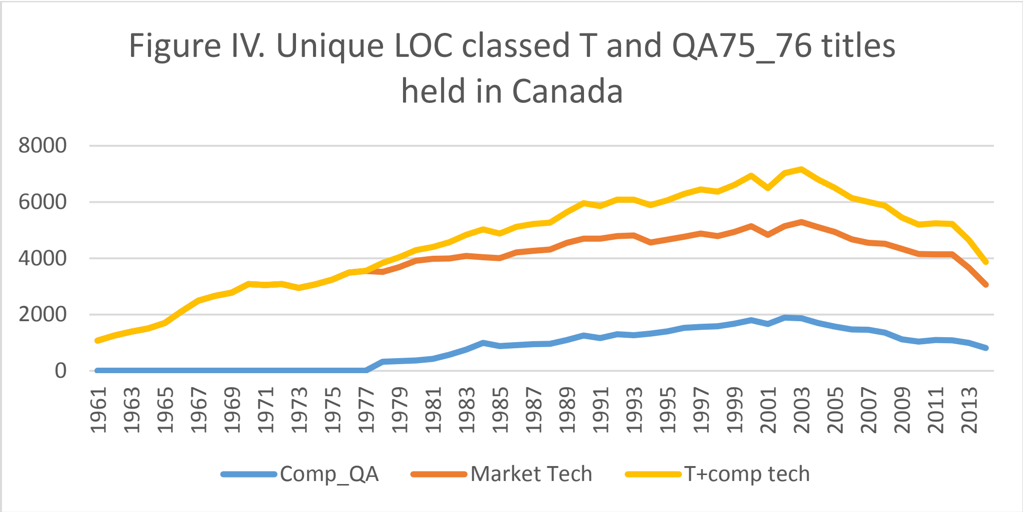
One issue that arises when using this approach to capture technical change in Canada is the source of the data. Unlike the US, there is no single library in the country such as the Library of Congress that is representative of the titles collected for and used by Canadians. For this reason, as we did in our previous work on IT innovation in Canada (Alexopoulos and Cohen (2012)), we employ book data collected from the catalogues of over 1000 Canadian libraries covered in the WorldCat database of the Online Computer Library Centre (OCLC). Although not all Canadian libraries are members of OCLC, membership is representative of all the major collections including the National Library of Canada, the country's largest public libraries (e.g. those in Toronto, Montreal and Vancouver), and all major university libraries. As such, these book data provide a comprehensive list of the major technology related titles available in Canada as identified though the assignment of technology and computer related Library of Congress (LOC) Classifications (i.e., the T class and QA75-77

[10] See, for example, the discussions in Basu, Fernald, and Kimball (2006) and Christiano, Eichenbaum and Vigfusson (2004).

classes). To avoid the double counting of titles, we de-duplicated the data on the basis of information in the titles' associated **MA**chine **R**eadable **C**atalogue **R**ecords.[11]

III.2. What do the new data tell us?

Our indices for Canada, presented below in Figure IV, cover the years the 1946-2014.[12] The most notable finding is that we do indeed see a turndown in early 2000s around the same time as productivity declined. This decline is seen when examining just titles in the T class related to market technologies (all T classed titles excluding those in the TT and TX groups), Computer science titles (in QA75-75) or the sum of the books in both categories.



An examination of publishing trends more generally suggest that this decline was not simply caused by a drop in the overall number of titles (since numbers in some sub-groups rise not fall during this time period). Similarly, it was not the result of budget contraction at

[11] MARC records contain identifiers such as the Library of Congress id number, and ISBN numbers which can be used to remove duplicates.
[12] The decision to omit the last few years of the sample removes biases related to issues concerning backlogs in cataloguing activities by libraries.

Canadian libraries for the simple reason that library budget did not typically contract during these years and the Canadian dollar was stronger than average for the later part of the time period.

Further support for the argument that a slowdown in technical change did take place during this time comes from south of the border where a drop innovative activity is visible in the US data (See Figure V). In short then, the Canadian data would seem to indicate that, overall, the timing of the slowdown in productivity growth was closed linked to a fall-off in technical change. We turn now to a more fine-grained analysis to determine the exact sectoral location of the trouble(s).

Figure V. Technical Change in the US

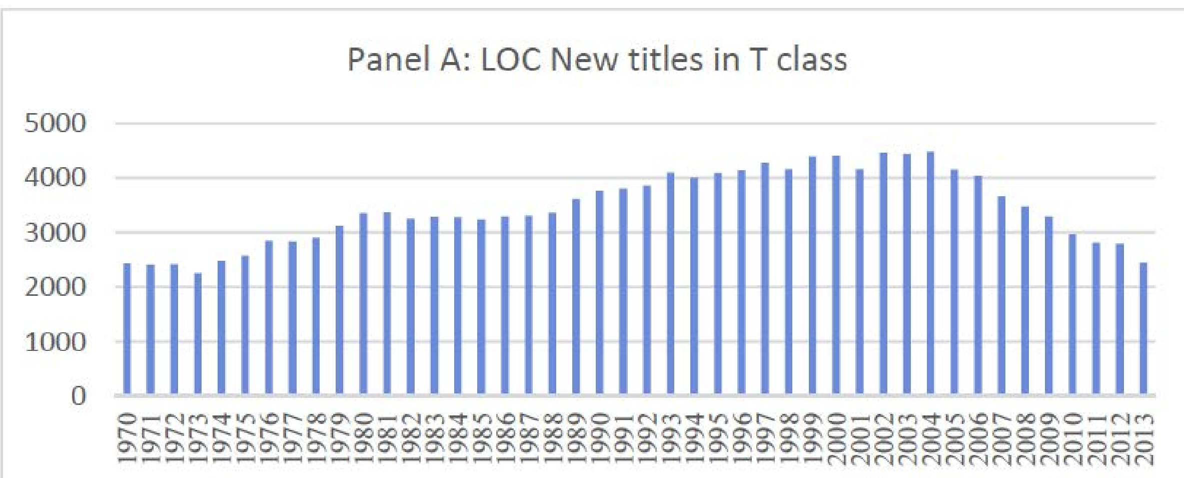
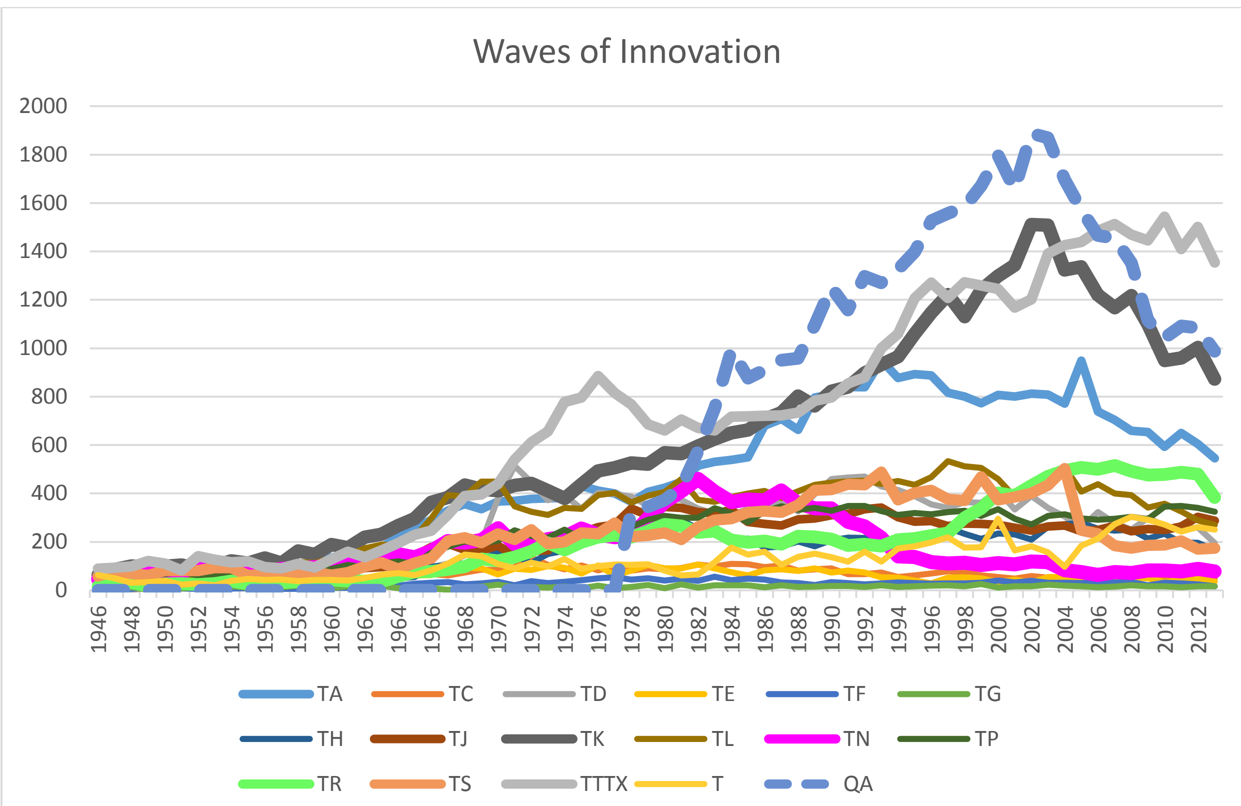


Figure VI graphs the raw series for subgroups of technology. Specifically, we include series for general technology (T subclass), general engineering (TA), hydraulic and ocean engineering, including the building of dams (TC), environmental and sanitary engineering (TD), Highways and Roads (TE), Railroads (TF), Bridge engineering (TG), Building construction (TH), Mechanical engineering and machinery (TJ), Electrical engineering and Electronics (TK), Transportation technologies (TL), Mining and Metallurgy (TN), Chemical engineering and technologies (TP), Photography including uses for digital cameras and medical radiology (TR), Manufacturing (TS), Home economics/food preparation, handicrafts, cloth manufacturing and design, and management of services such as hotels and restaurants (TTTX), and books in the QA75-77 class (QA) related to computer science.

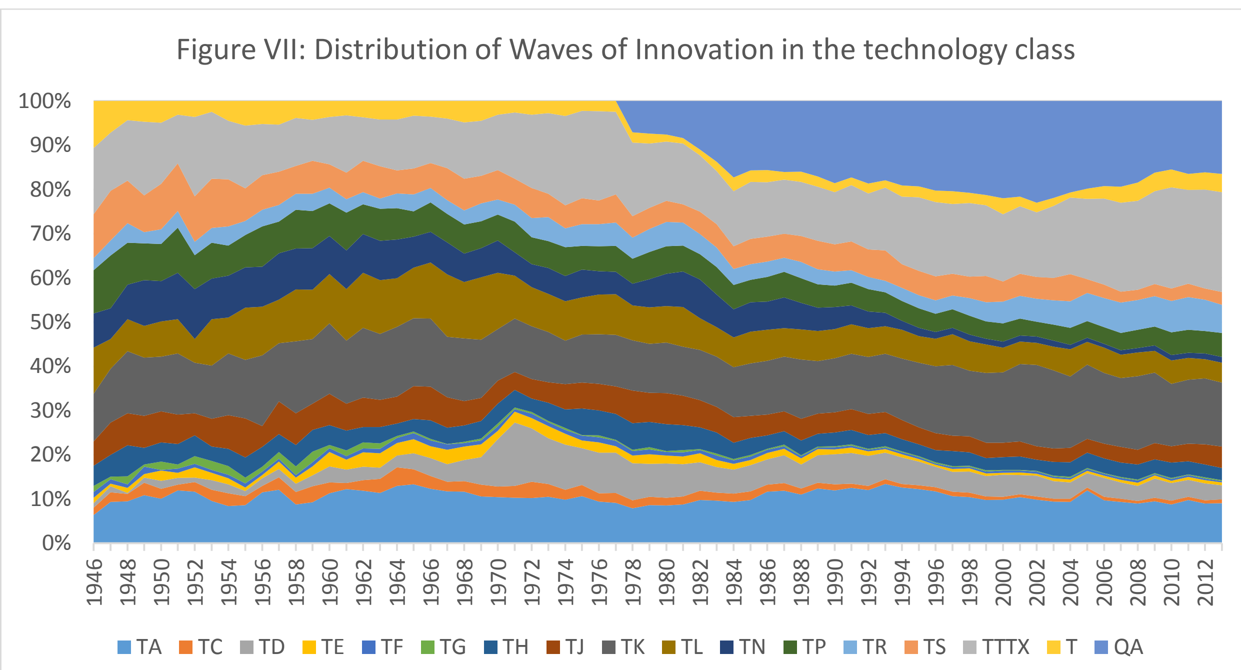
Figure VI. Canadian Title Counts



The trends show that the largest decreases were centered in the QA and TK groups. These include basic computing (QA) and electrical (TK) which encompasses Telecom, computer hardware, and computer networks. TA, general engineering, also started to decline in the 1990s, with other sharp declines seen in technology associated with manufacturing (TS). Technical change in areas related to mining and natural resources (TN) also fell, but, as can be seen, in these areas the turn down started even earlier.

On the other hand, in a few areas there was modest growth post 2003, principally in TTTX and TR. As we might expect, these groups, more linked to the services, did not experience the same decline in MFP. Specifically, the TTTX groups contains innovations tied to the hotel and restaurant industries, food prep and other services, while TR captures innovations in areas such as cinematography, photography, and radiography, which have applications in areas such as advertising, TV, entertainment, medicine, surveying, security, etc.

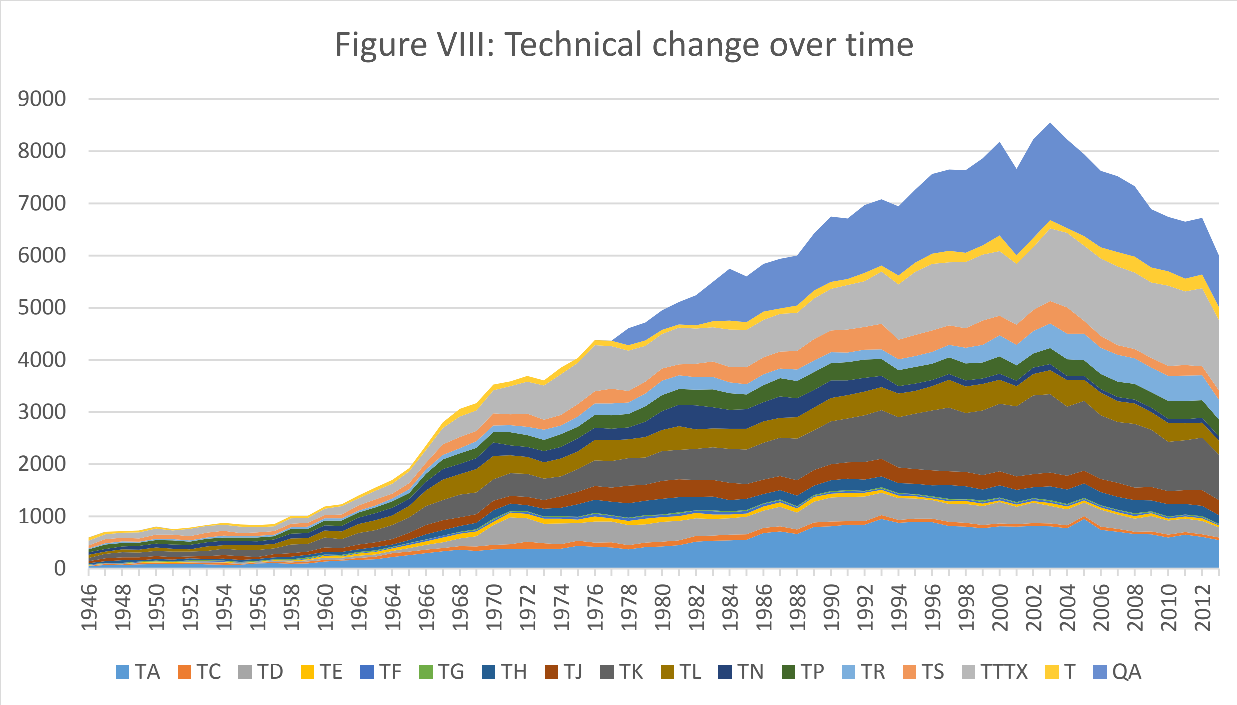
An examination of the percent of titles in each of the T categories each year (i.e., the number of new titles in the technology/computer subclass in year j divided by all new titles in the technology and computer subclasses) gives additional insight into the types of titles that were being acquired in Canada. This breakdown is shown in Figure VII and highlights the extent of the changes.



While TN (mining) is a non-trivial area of innovation in the early post-war period, it is clear that it now accounts for very little, in relative terms, of the new innovations. TL (automotive), approximately the same as Mining in terms of innovations in the late 1940s, has declined much less in the ensuing 60 or so years. The largest changes have been in the IT related areas. Specifically, the computer class (QA) rose to prominence in the 1980s and 1990s, but has lost ground more recently. A rise in TK is also seen following the introduction of personal computers and the internet with a modest decline beginning in the late 2000s. The only areas increasing near the end of the sample is TP (Chemical technologies which includes some biotech innovations), as well as the TR and TTTX groups discussed above.[13]

The combination of these graphs is presented in Figure VIII. Here it is clear that since the early 2000s the pace of innovation across most areas has fallen with the areas related to computer technologies and electronics (TK and QA) playing a major role in the decline. While the correlations with the drop in productivity give some support for the hypothesis that a slowdown in IT innovation was a leading contributor to the lackluster productivity growth, a more formal investigation into the statistical relationship between the indicators and productivity is necessary before conclusions can be drawn.

[13] Interestingly, Gu and Lee (2013) point out that the Information and Culture sector's labour productivity and multi-factor productivity grew during the 2000-2010 period. This would be consistent with an increase in innovation captured by the TR class.



IV. Did Technical Change Contribute to The Great "Moderation"?

To determine what impact the changing landscape in technical change had on Canadian Multifactor productivity, MFP, we ran a series of VARs. Specifically, we examined bivariate VARS of the form:

$$Y_t = \alpha + \sum_{j=1}^{k} \rho_j Y_{t-j} + \varepsilon_t$$

on annual data from 1961-2014 where the starting date was determined by the availability of MFP data from Statistics Canada and the and the end date determined by the availability of the book holdings data. We estimated cases with k={2,3} where Y_t = [ln(Productivity$_t$), ln(tech index$_t$)] ′, with and without time trends included, as well as a case with both productivity and the tech indices in first differences. More than one year of lags was selected to account for the fact that many of the titles (and innovations) are American, and our previous work on Canada suggested that US innovations are more likely adopted in Canada (if they are) within 1-3 years. Technology shocks are identified using a Cholesky decomposition. Specifically, our identifying assumption, similar to the one used in our previous work, as well as Christiansen (2008) and in Shea (1998), is that a technology shock only affects MFP with a lag. Since the different specifications had very similar predictions, we generally present the cases for VARs in levels with 2 lags and a trend and or VARs in first differences in what follows. Due to space considerations, we typically focus our discussion on areas where the effects of the technology shocks are found to be significant.

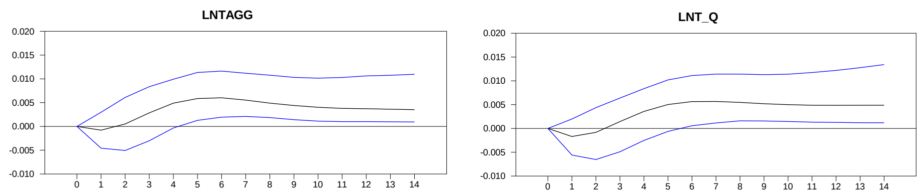
Aggregate Technology shocks

Overall we find that aggregate business sector productivity (MFP^{Agg}) is Granger-caused by the aggregate technology measures (ie. all T titles and all T+QA75-77 titles) at the 5% and 10% levels with no evidence of reverse causality. When we explored the relationship between the indicators and MFP in the goods and service producing sectors, we found the technology measures significantly Granger-caused MFP^{gds} but not MFP^{serv} again indicating that the slowdown in innovation appears to have affected sectors such as manufacturing, mining and construction the most.

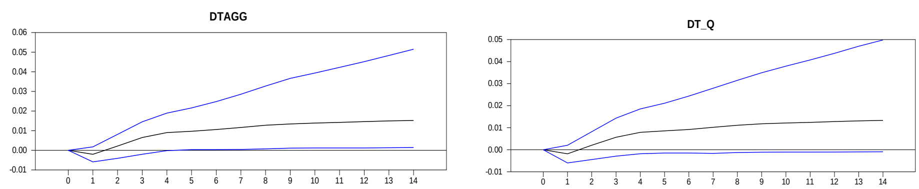
The impulse response functions confirm that positive technology shocks during this period increases aggregate productivity and the goods sector productivity significantly over the following 10-15 years with the peak impact occurring after 5 years. In contrast, there was no significant impact on service sector MFP. As the responses displayed in Figure IX (along with 90% confidence bands) show, the effects of the shocks are long lasting but often the results are only significant after few years (likely due to the time lags associated with Canadian adoption of US innovations).

Figure IX. Responses of Canadian MFP to a positive 1- standard deviation aggregate technology shocks.

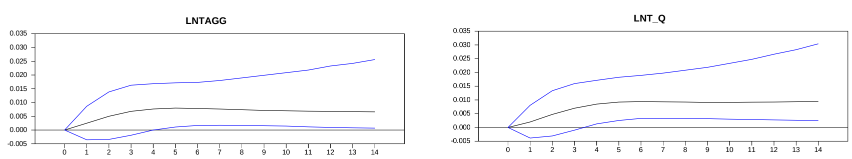
Panel A: Aggregate Business Sector MFP responses from VARs in levels



Panel B: Aggregate Business Sector MFP responses from VARs in first differences



Panel C: Goods producing Business Sector MFP responses from VARs in levels



Panel D: Goods producing Business Sector MFP responses from VARs in first differences

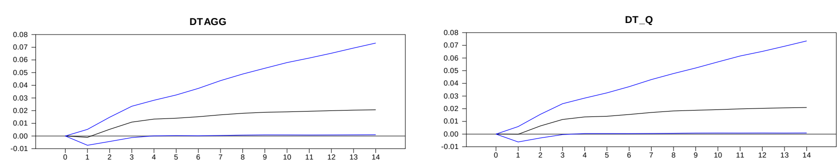


Table 2 displays the associated variance decompositions for the cases for the VAR in levels and the VARs in growth rates for both aggregate business MFP and business MFP for the goods producing sector (MFP^{Gds}). The results for the aggregate and goods producing sectors suggest that technology shocks appear to be related to a non-trivial fractions of fluctuations in Canadian MFP (and its growth rates). The fraction of the variation grows somewhat over time, and is similar to the effects seen for the US economy.[14]

Table 2. Variance Decompositions

Horizon	Level $\ln(MFP^{agg})$	Level $\ln(MFP^{gds})$	Growth in MFP^{agg}	Growth in MFP^{gds}
T class technologies				
3	1.5	2.2	9.8	8.2
	(0.1,11.2)	(0.1,14.2)	(2.3,23.9)	(1.2,21.4)
6	13.8	9.0	18.1	13.6
	(2.1,37.4)	(0.6,32.9)	(4.4,38.8)	(2.1,32.6)
9	25.2	14.6	19.5	14.5
	(5.1,52.7)	(1.3,41.5)	(4.6,42.1)	(2.1,37.4)
12	29.4	17.6	20.1	14.8
	(7.1,61.5)	(1.8,47.7)	(4.7,44.8)	(2.1,40.3)
T class and QA75-77 technologies				
3	1.7	2.2	8.4	7.9
	(0.1,12.2)	(0.1,13.4)	(1.6,21.6)	(1.0,21.6)
6	10.4	12.3	14.7	12.2
	(1.7,30.2)	(1.2,36.6)	(2.7,34.9)	(1.6,30.9)
9	22.1	21.5	15.8	13.3
	(4.2,49.5)	(2.6,50.3)	(2.8,39.0)	(1.6,36.5)
12	29.4	26.8	16.2	13.6
	(6.1,60.9)	(3.9,59.1)	(2.8,41.6)	(1.7,38.8)

Note: Numbers in brackets represent the 90% confidence bands.

Disaggregate Technology shocks

Not all innovations are created equally in terms of their impact on productivity. Therefore, we examined the productivity shocks for a number of sub-categories of technical change to further our understanding of what types of innovations (or lack thereof) appear to have affected Canada's productivity. Specifically, we examined the effects of shocks related to

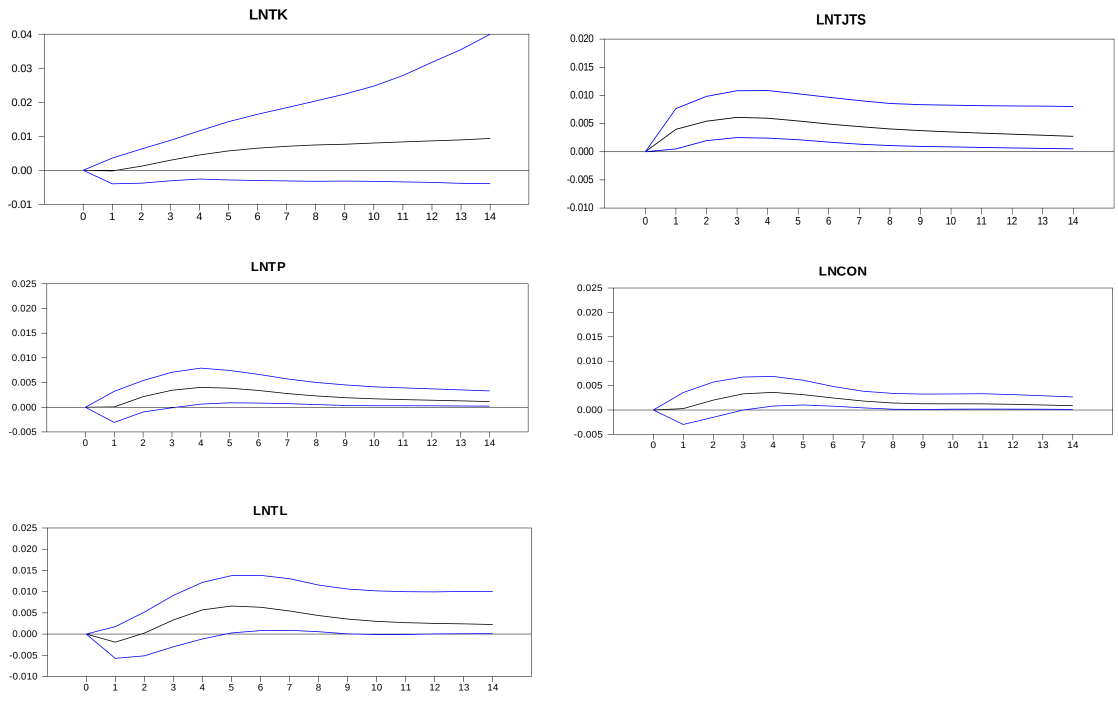
[14] See Alexopoulos and Cohen (2018) and Alexopoulos (2011) for US values.

manufacturing and mechanical technologies (i.e., TJ+TS technologies), Chemical technologies (TP), transportation technologies (TL), mining technologies (TN), construction related technologies (TH, TC,TE, TG), and electrical technologies (TK). For these cases, we found that the transportation technologies, Chemical Technologies and construction related technologies Granger-caused aggregate MFP at the 10% level, with only the mechanical/manufacturing technologies Granger-causing MFP^{agg} at the 5% level. The others cases were not significant at conventional levels. For the goods producing sector, we found evidence that electrical technologies (TK) and mechanical/manufacturing technologies (TJTS) Granger-caused MFP^{gds} at just under a 1% level. None of the technology indicators consistently Granger-caused service sector MFP at the conventional levels of significance.

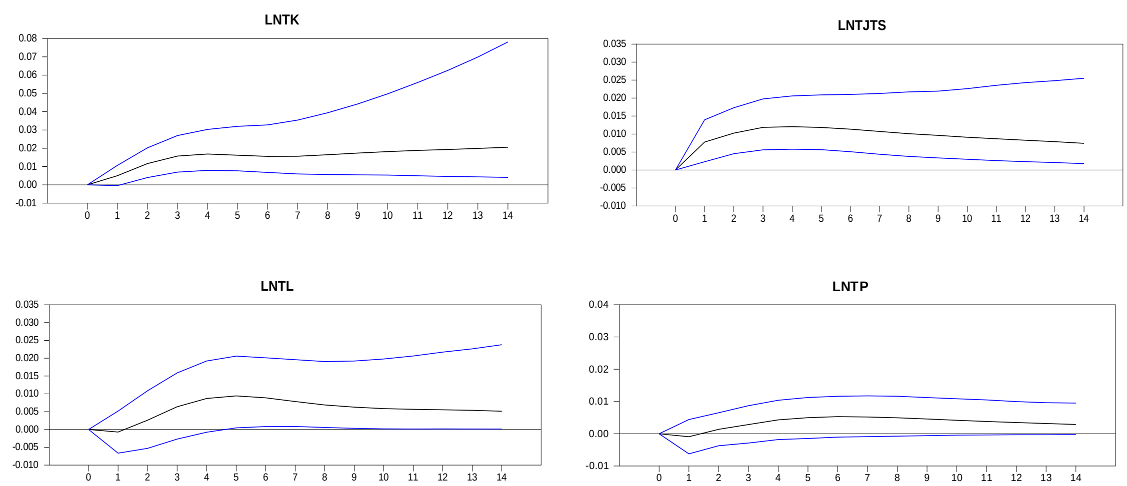
Figure X presents selected responses for cases where we found significant responses to the various technology shocks. Overall, paths of the responses are similar to cases seen for the aggregate technology. In most cases, we see evidence that the peak impact is felt 4-5 years following the shock with a limited initial impact. The one exception to this was the response to the mechanical/manufacturing shocks. In these cases, it would appear that MFP^{agg} and MFP^{gds} significantly increase within the first few years.

Figure X. Selected Responses of Business Sector MFP, and Goods-producing sector MFP to positive 1 standard deviation technology shocks.

Panel A: Aggregate Business Sector MFP



Panel B: Goods-Producing Sectors MFP



Note: The responses are percentage deviations of MFP to positive 1 standard deviation technology shocks. Each period is one year. The upper and lower bands represent the 90% confidence bands. The responses displayed are from the bi-variate VARs with two lags and a trend. Indicators are ordered last and shocks are identified using a Cholesky decomposition.

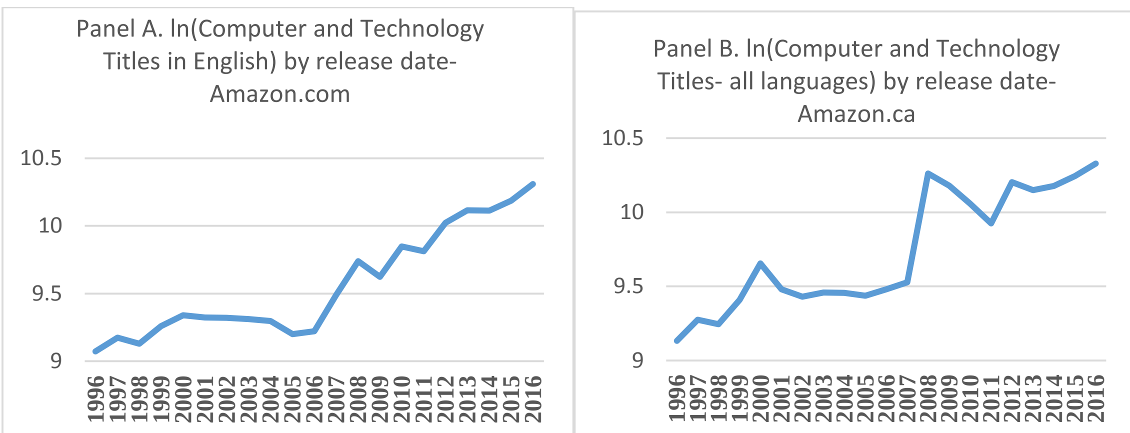
Which of these shocks are most related to the variance in productivity? Overall, the results point to the TJTS technologies, and the TK technologies playing the largest roles. By the 6-year horizon, approximately 21% of the variation in MFP^{agg} was attributable to the TJTS innovations, with the share growing to over 30%. When examining the case of electrical technologies, the estimated share at the 6-year horizon was about 10% rising to over 35% by year 12. The effects of the Transportation technologies also appeared to be in the 15-25% range in the 6-12 year horizon range. In contrast, construction and chemical technologies accounted for only about 10%. Similar results were found when we examined the relationships with MFP in the goods producing sectors. In these cases, the variations attributable to the TJTS and TK technologies were about 11% by the year 3 horizon with the shares growing to 41% and 51% respectively by year 12. The fluctuation in MFP^{gds} attributable to chemical technologies and transportation technologies remained in the range of 8%-15%. For the service sector MFP, the estimates suggested the largest contributors to fluctuations in productivity would come from the TK (electrical technologies inc. networks and telecommunications) and TR (photographic/digital technologies linked to areas like advertising, medical services, arts and entertainment sectors, surveying services etc.). However, the confidence bands in these cases were generally too large to conclude a significant impact at the 10% level.

V. The End of the Great "Moderation"?

While predicting the future path of technical change is extremely difficult, some information about new innovations can be found by looking at what is happening to innovation in the US. Much of our innovations are "imported" from our neighbour to the south, and currently we are seeing some indications that new, potentially revolutionary technologies are being commercialized and adopted there.

The evidence on this comes from a variety of sources. First, we have noticed that the US English language book based indicators have started to show a turnaround in the number of technical books available (See Figure XI, Panel A). The pattern is also seen in the number of titles (in all languages), that is available for purchase on Amazon.ca (Figure XI, Panel B). Therefore, there is some optimism that the future of innovation is brighter than it has been in the past few decades.[15]

Figure XI.



What is causing the increase? To obtain some insights into this question, we examined the break-down in the number of Computer and Technology titles by sub-class. The top categories are shown in Figure XII, Panel A's word cloud (where the font size varies with the frequency of titles in the category). Panel B, of the same figure depicts change in the top 25 sub-categories over time. Together, these figures indicated that the growth in new titles are mostly focused in areas related to Artificial Intelligence, Computer security, Cloud computing, Big Data and CAD (related to advanced manufacturing). In particular, 47% of the recent

[15] Some of the increase is due to the availability of self-published and e-titles. However, even without these, there is a noticeable increase in the most recent years.

computer science titles are related to the field of AI, and 42% of the AI titles are related to robotics.

Figure XII.

Panel A. Word Cloud of top 10 technology subgroups in last 5 years

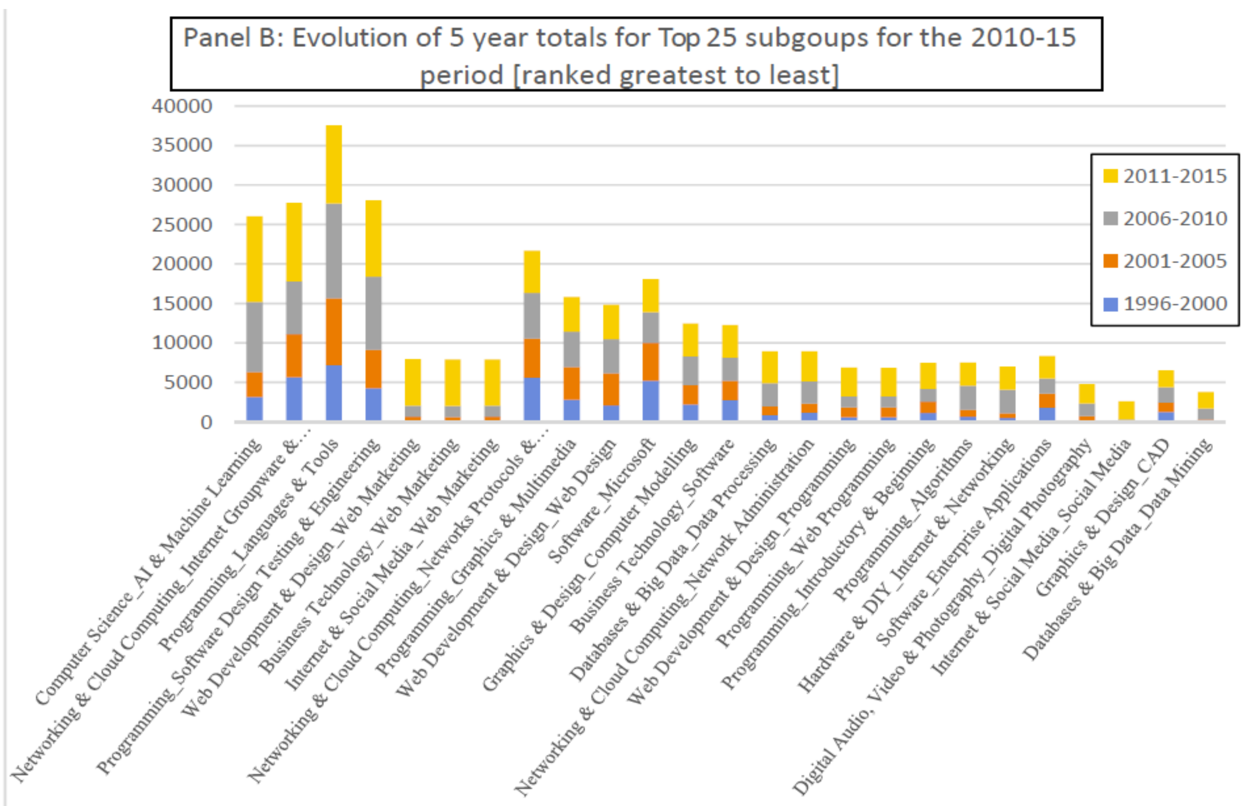
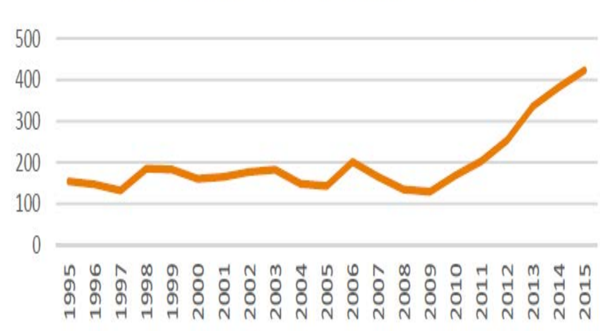


Figure XIII provides additional evidence supporting the case for increasing innovation in these areas. Specifically, Panel A shows that there has been an increase in the number of patents granted by the USPTO in both areas (robots and AI). Panel B shows an dramatic increase in the number of articles published in US and Canadian Newspapers discussing the innovations, and Panel C, shows the trends in articles discussing employment and these specific technologies. Overall, the patent statistics and the discussion in newspapers strongly indicates that there is increased innovation (especially within the past 5 years) with significant potential for further commercialization and diffusion of these technologies in the near future.

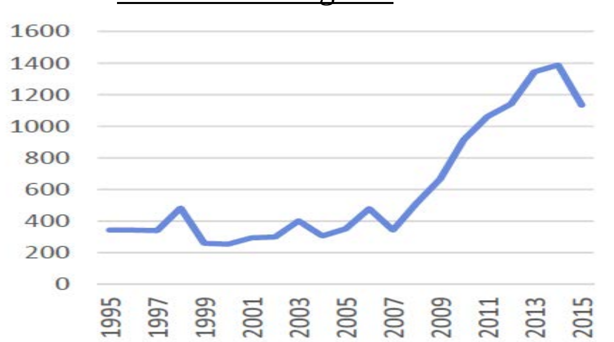
Figure XIII.

Panel A. Patents Granted by the US Patent and Trademark office

<u>Robots</u>

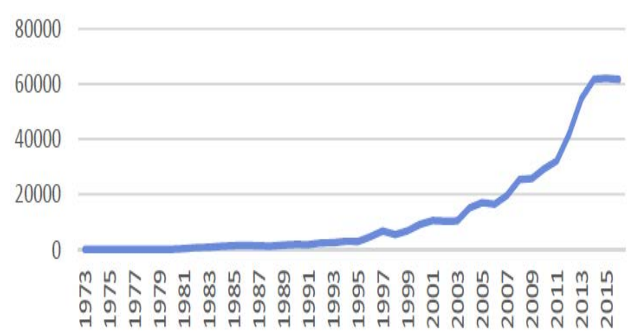


<u>Artificial Intelligence</u>

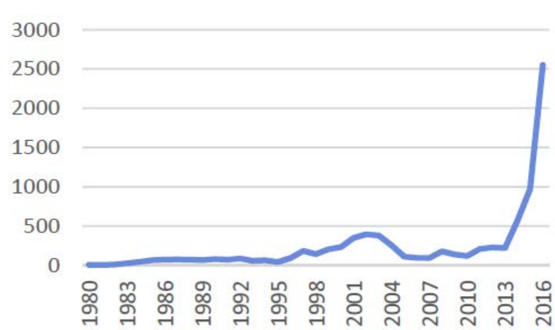


Panel B. Factiva Articles

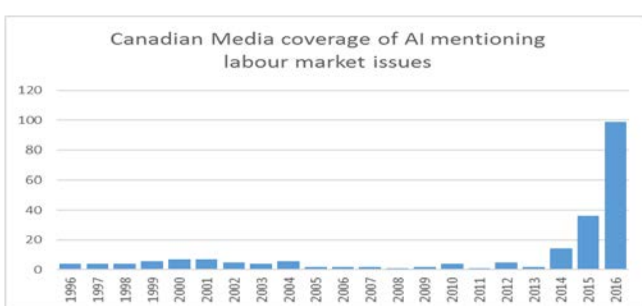
<u>Robots</u>



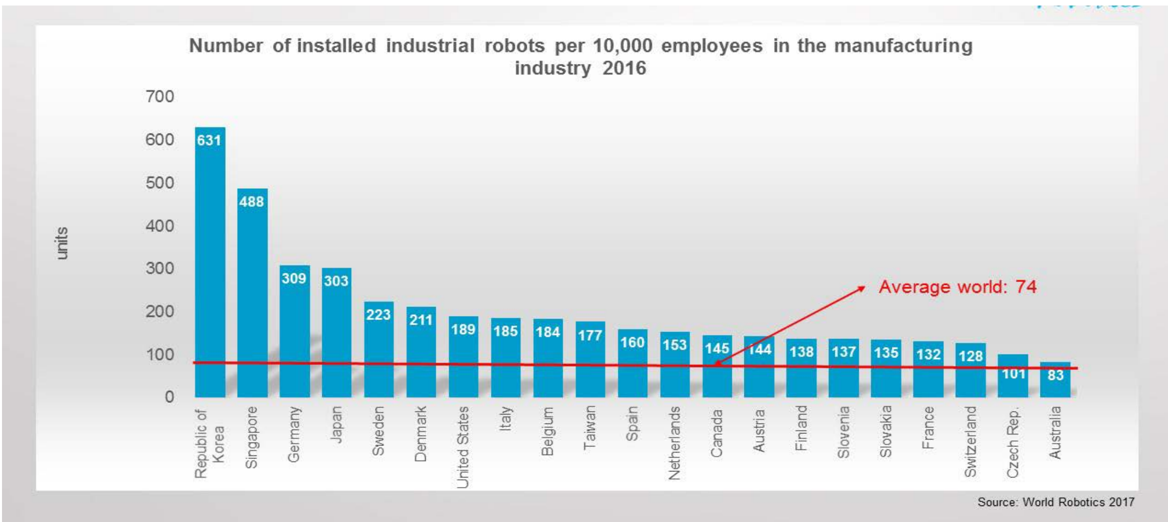
<u>Artificial Intelligence</u>



Panel C.



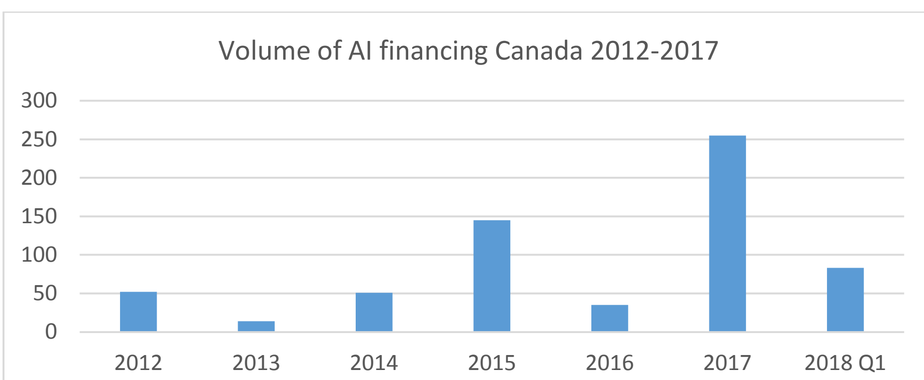
Will this innovation help reinvigorate productivity growth in Canada? The answer, of course, will depend on adoption. Currently, we lag behind countries such as Japan, Germany and the US (See Figure XIV) in the adoption of robots.



Source: https://ifr.org/ifr-press-releases/news/robot-density-rises-globally

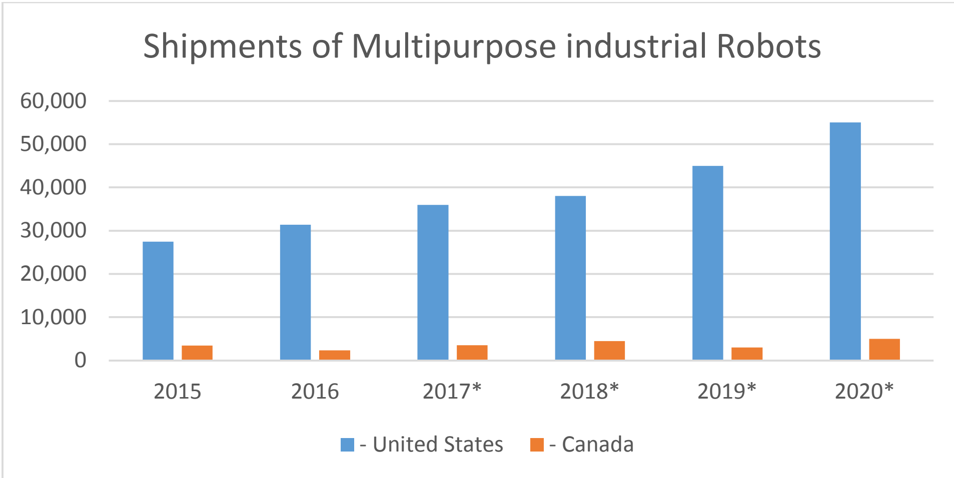
There continues to be some investment into robotic technology and AI in Canada (Figures XV and XVI). However, a gap between the pace of adoption in the US relative to Canada is still apparent.

Figure XV.



Sources: CB insights, PWC money tree Canada reports

Figure XVI.



Note: Statistics are from the IFR World Report.
https://ifr.org/downloads/press/Executive_Summary_WR_2017_Industrial_Robots.pdf. * represents the IFR's estimates of shipments.

Given that the labour productivity gains from 1993-2007) tied to the introduction of robots, has been estimated to be larger than that associated with the adoption of the steam engine from 1850-1910, for the US, it would seem that additional adoption by manufacturers in Canada should help boost productivity.[16] This is supported by our regression results since AI and robotics are both technologies that are linked to innovations in the TK and TJTS classes – the main drivers of MFP seen during the 1961-2014 period. Moreover, an analysis of the industry tags associate with the articles from Factiva related to Artificial Intelligence and Canada suggests that a number of industries should benefit from advances in these technologies. In particular, the word cloud in Figure XVI shows the industries discussed where the size of the label reflects the relative frequency in the articles. Industries mentioned include, among others, the computer and electronic industries, telecommunication, machinery, pharmaceuticals, retail, finance, agriculture

[16] See Crafts (2004) and Graetz and Michaels (2015)

and biotechnology, and as Eichengreen (2015) points out, the impact of a technology will be determined by its range of adaptability and adoption.[17]

Figure XVII. Factiva Industry tags associated with AI in the Canada

VI. Conclusion

Our results indicate, first, that there was a slowdown in productivity growth in Canada in the first decade or so of the 21th century, very similar to the one observed in the US. Second, our VAR analysis revealed that technology shocks both in aggregate and in the areas of manufacturing/mechanical and electric played an important role in driving the fall off in productivity growth. We also found that the decline in productivity growth was more sector specific in Canada than is usually realized with the fall off most marked among goods producers and least in services. As it happens, these results were echoed in the technical change numbers where the poorest performers were linked to mining and manufacturing.

The concern among a number of prominent economists is that this recent slowdown is just the start of long period of secular stagnation, powered at least in part by lackluster technological advances. Is it correct to view the recent past as good predictor of future trends? The answer, we believe, is no. We have seen slowdowns and speed ups in the past – our

[17] See Alexopoulos and Cohen (2018) for additional evidence on the potential for the use and spread of AI and Robotics in the US, and a comparison of these technologies to major GPT technologies in the past.

previous work indicates that technical change comes in waves of lesser and greater intensity – which suggests that this time is probably not different. And there are tentative signs, especially, but not only, in the US, that a rebound is underway. Based on our textual analysis and confirmed by linked-in, factiva and other sources, the major new areas include, among others, AI, and robotics.

As we report in the final section of the paper, the recent turnaround in innovative activity in the US bodes well for the future of productivity and economic growth there. Can the same be said for Canada? Given the usual adoption lags that typify the uptake of new technologies in Canada, the future here is less certain but we can, with some confidence, make two observations. First, the new technologies as captured by our Amazon indicators are (almost) as accessible in Canada as they are in the US and, second, there is no reason to believe that this time is different. If we are correct, then the issues that Canadian policy makers will have to confront are those associated with stagnation but, quite the contrary, are ones, such employment opportunities, training requirements, and income distribution, thrown up by disruptive growth.

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