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Weak ICT Investment in Canada and the United States: the Role of Cloud Computing

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Abstract

After robust growth in ICT investment in Canada and the United States during the 1980s and 1990s, growth in ICT investment started to slow after 2000 and its share in GDP entered a downward trajectory. In an increasingly digitalized economy, weak ICT investment seems puzzling. To explain this trend, this report focuses on two facets of the changing ICT spending pattern driven by the rise in cloud computing starting in the mid-2000s. Instead of investing in ICT capital goods, organizations now purchase cloud services from cloud service providers that appear to be more efficient in producing computing services. Second, cloud service providers undertake substantial own-account investment in ICT equipment which is not counted in official statistics. Based on input-output tables, we find that the impact of cloud computing on the ICT spending pattern is potentially substantial: during the 2006-2014 period, the purchase of cloud services rose at an annual rate of 25.3 per cent to reach $2,554 million CAD in Canada and at an annual rate of 20.4 per cent to reach $32.1 billion USD in the United States. During this period, adding own-account ICT equipment investment by the IT service sector results in additional 1.71 percentage-points in annual growth for nominal ICT investment in Canada and additional 1.12 percentage-points in the United States.

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Executive Summary

With dramatic changes brought about by digital computing and communication technology, weak ICT investment in Canada and the United States seems puzzling. ICT investment grew at a much slower rate after 2000. Also, ICT investment as a share of nominal GDP entered a downward trajectory since the early 2000s. The slowdown in ICT investment as a share of GDP following the burst of the dot-com bubble in 2001 continued until the present.

This report explores the potential role of cloud computing in explaining the weak ICT investment in Canada and the United States. We focus on the rapid diffusion of cloud computing in the two countries starting in the mid-2000s. Cloud computing is important in understanding the weak ICT investment statistics since an increasing number of organizations have adopted cloud computing and the adoption of such new computing system has important implications for their ICT spending pattern.

Two Issues with rising cloud computing

First, cloud computing has changed not only the way organizations access computing resources but also the way they pay for such technologies. With cloud computing, they access computing resources in the form of services. Hence, it allows them to divert capital expenditure on ICT tangibles and intangibles to purchase of intermediate services since cloud computing does not require ICT infrastructure on premises. Instead, cloud service providers now invest in ICT capital goods and they appear to be more efficient in producing computing services.

Second, there is a number of signs that major cloud service providers engage in own-account investment (assembling servers and building other cloud infrastructures internally). A large increase in the capital expenditure reflected in their financial filings does not seem to translate into an equivalent increase in the official ICT equipment investment statistics. Indeed, input-output tables indicate that they have purchased a large amount of computer and electronics components as intermediate goods especially since the mid-2000s suggesting that they have assembled ICT equipment internally.

Some non-market production is included in the official statistics such as own-account software production (included as "own-account software investment" in the United States and "Own-account software design and development services" in Canada). However own-account ICT equipment production is not included in the accounts. Therefore, we believe that weak ICT investment statistics is explained in part by this measurement issue.

Empirical Approach

In order to assess the impact of these two facets of cloud spending on ICT investment in Canada and the United States, we carry out a quantitative analysis using the data from the detailed input-output tables published by Statistics Canada and the Bureau of Economic Analysis. For the first issue, we conduct a simple counterfactual analysis exploiting a break in the time-series of the intensity (defined as a share of GDP) of the intermediate purchase of computing services made in the total economy. We assume that the break was induced by a rise of cloud computing. Second, we estimate the value of own-account investment in ICT equipment by cloud service providers based on the value of their input purchase of computer and electronics components adjusted for the value added from assembling and installing ICT equipment.

Results

We summarize our main findings as follows. First, our estimates indicate that organizations are increasingly shifting their resources to purchasing cloud services. We find that the purchase of cloud services in the total economy grew substantially since the mid 2000s in both Canada and the United States:

- In Canada, the purchase of cloud services stood at $2,554 million CAD in 2014, up from $420 million CAD in 2006 (25.3 per cent annual growth).

- In the United States, the purchase of cloud services reached $32.1 billion USD, up from $7.3 billion USD in 2006 (20.4 per cent annual growth).

Second, we find that own-account investment by "IT service sectors" (which presumably cover core activities of cloud service providers) was significant in Canada and the United States:

- Own-account investment in Canada reached $5.1 billion CAD by 2014, up from $1.7 billion in 2006 (14.5 per cent annual growth).

- In the United States, it reached $53.9 billion USD in 2014, up from $22.6 billion USD in 2006 (12.1 per cent annual growth).

Our estimates are consistent with the data from external sources including a private sector consultancy and financial filings of major cloud service providers in the United States.

Most importantly, adding our estimates of own-account investment to ICT investment statistics changes the trend in the ICT investment series significantly. For Canada, ICT investment grew by 1.71 percentage-points more per year during the 2006-2014 period if own-account investment is added to the official statistics (2.19 per cent instead of 0.48 per cent). Also, ICT investment as a share of GDP somewhat stabilizes after 2006 instead of falling. From 2.70 per cent in 2005, the share falls to only 2.65 per cent instead of 2.14 per cent in 2014.

Similarly, in the United States, augmenting ICT investment with own-account investment leads to additional 1.12 percentage points for the annual growth rate during the 2006-2014 period. This suggests that ICT investment grew at an annual rate of 3.34 per cent instead of 2.22 per cent during this period. Adding own-account investment leads to a slight upward trend in the ICT investment as a share of GDP from 2006. By 2014, the share recovers to 3.73 per cent for the share from 3.22 per cent in 2005 instead of falling to 3.11 per cent.

The key takeaway is that the ICT spending in both Canada and the United States did respond to the rise of cloud computing from the mid-2000s. Our results imply that a significant part of the "weak ICT investment story" can be explained by own-account equipment investment by cloud service providers. At the same time, some portion of ICT investment could have been redirected permanently to other part of the economy as organizations shift their resources from expenditure on ICT capital to current expenditure on computing services (*e.g.* purchasing cloud services such as SaaS, PaaS, and IaaS).

This report is exploratory in nature in addressing the two important facets of the changing ICT spending pattern driven by a rise of cloud computing. This report proposes a line of research on the impact of cloud computing on the ICT spending pattern in Canada and the United States. In doing so, this report also addresses a need for official data on cloud services. We hope our research leads to further debate on cloud computing as well as a better data collection on the cloud services sector by statistics officials.

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I. Introduction

Since the mid-1970s, we have experienced dramatic changes brought about by digital computing and communication technology. With the mass production and a rapid diffusion of digital logic circuits and its derivatives (*e.g.* computer, cellular phones, the internet), digital information and communication technologies have transformed traditional production and business techniques. As a result, attention has been increasingly devoted to the role of information and communication technology (ICT) investment in capital formation and in productivity growth (*e.g.* Thomas, 2016).

ICT investment in Canada and the United States has been weak since 2000. ICT investment (in the total economy) as a share of nominal GDP has been on a downward trajectory since 2000 in both countries (see Chart 1). The share fell significantly following the burst of the dot-com bubble and it has not recovered to the level observed around 2000.

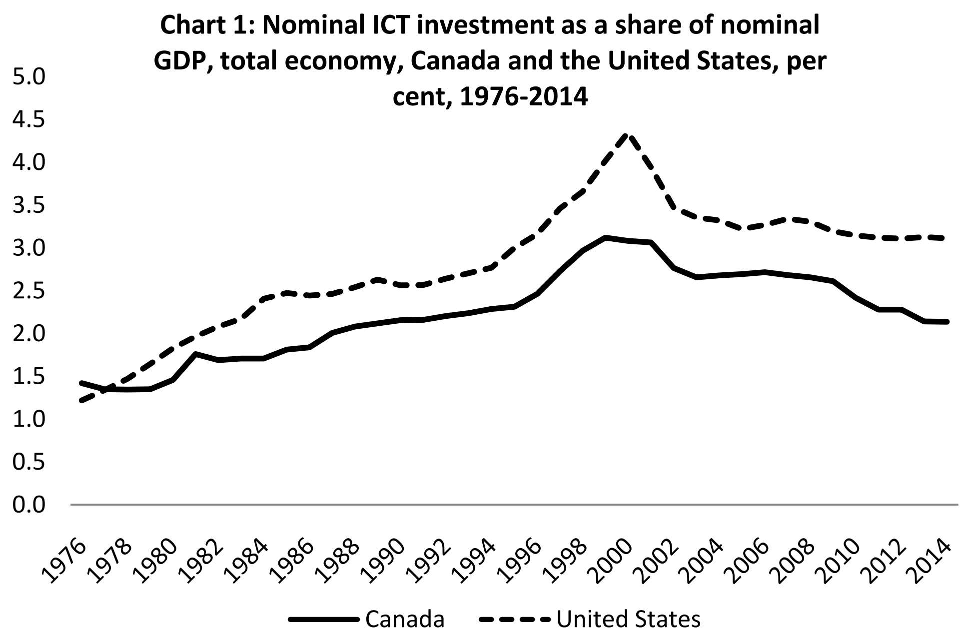

Chart 1: Nominal ICT investment as a share of nominal GDP, total economy, Canada and the United States, per cent, 1976-2014

Note: ICT investment consists of investment in ICT equipment and investment in computer software and databases.
Source: CSLS database for ICT investment. Available at http://www.csls.ca/data/ict.asp

[1] This reported was written by CSLS economist Myeongwan Kim under the supervision of CSLS Executive Director Andrew Sharpe for Innovation, Science, Economic Development Canada. The Centre for the Study of Living Standards would like to thank Innovation, Science, Economic Development Canada for financial support for this research. The author thanks Andrew Sharpe, Bert Waslander, and Jianmin Tang at Innovation, Science, Economic Development Canada for comments. The author also thanks officials at Statistics Canada, especially Andreas Trau in the Industry Accounts Division for providing us with data.

Table 1: Annual growth rates of ICT investment, per cent, Canada and the United States, 1997-2014

	Canada		United States	
	Panel A: ICT investment			
	Nominal	Real	Nominal	Real
1976-1981	17.42	6.50	22.50	26.15
1976-2000	10.81	8.69	11.95	13.19
1981-1989	10.33	9.00	11.33	15.94
1989-2000	8.27	9.46	10.52	18.09
2000-2014	1.55	3.80	1.35	4.30
2000-2006	2.98	8.30	0.20	4.99
2006-2014	0.48	0.55	2.22	3.79
	Panel B: ICT equipment			
	Nominal	Real	Nominal	Real
1976-1981	16.95	3.63	24.25	30.61
1976-2000	9.50	6.97	11.95	20.95
1981-1989	7.66	5.41	8.95	15.07
1989-2000	7.60	9.69	8.89	21.10
2000-2014	-1.38	3.56	-1.67	4.63
2000-2006	0.56	9.75	-3.24	6.17
2006-2014	-2.82	-0.85	-0.48	3.50
	Panel C: Computer software and databases			
	Nominal	Real	Nominal	Real
1976-1981	19.97	12.81	18.27	15.53
1976-2000	14.96	11.46	15.14	15.66
1981-1989	19.51	13.71	16.56	17.49
1989-2000	9.61	9.25	12.74	14.41
2000-2014	5.01	4.02	3.74	4.06
2000-2006	6.70	6.78	3.45	4.28
2006-2014	3.76	2.00	3.95	3.90

Note: Real ICT investment in Canada is based on Constant Prices (2007 CAD, millions). Real ICT investment in the United States is based on Chained Prices (2009 USD, millions).
Source: The CSLS database on ICT investment. Available at http://www.csls.ca/data/ict.asp

Weak ICT investment can also be observed in terms of an annual growth rate. Table 1 reports annual growth rates of both nominal and real ICT investment (total, ICT equipment, and software and databases) in Canada and the United States. We observe a general trend of the decreasing annual growth rate in both nominal and real terms over time. Notably, the annual increase decelerates substantially after 2000 in both countries. This is true for the two components of ICT investment: ICT equipment and computer software and databases (see Panel B and C in Table 1).[2]

[2] Note that during the 1970s and 1980s, the aggregate price of ICT investment in Canada increased. Hence, the annual growth rate in nominal terms is higher than that in real terms. The aggregate price of ICT investment in

Given a rapid diffusion of information and communication technologies, the downward trend in ICT investment (as a share of GDP and as a growth rate) seems puzzling. Among the other factors that could have contributed to the weak ICT investment, this report focuses on two important facets of the changing ICT spending pattern in light of a rising adoption of cloud computing.

Cloud computing has brought about a big change in accessing computing services for firms, households and governments. A transition to this new computing platform allows users to do computing on a network of off-site computing resources accessed through the internet. Cloud computing provides firms with a new model for accessing computing resources that can be easily provisioned, customized, scaled up or down to meet varying needs.

Relevant to our analysis is that cloud computing has changed how organizations budget and pay for technologies: organizations can access computing resources by purchasing services rather than by direct fixed investment in related ICT tangibles and intangibles (trade capital expense for variable expense). In turn, cloud service providers now invest in ICT capital goods to provide computing services but they can spread out the overhead cost over their customers. Cloud service providers are much more efficient in producing computing services since they can pool resources and allocate them based on an on-demand basis. This implies that a given unit of cloud-related capital goods can generate more services than the conventional computing system. We argue that this is likely to have led to a decline in the demand for ICT capital goods on net, and hence weak ICT investment.

Indeed, the rate of ICT resource utilization tends to be higher among firms adopting cloud computing[3] and that nearly 93 per cent of organizations in North America have already adopted *at least one* cloud service.[4] For example, the number of server units theoretically required for business operations can be reduced greatly due to improved efficiency via integration of conventional computing resources into cloud-based infrastructure. The impact of cloud computing on ICT investment is expected to be larger in the near future as full migration to a cloud-based system among firms gains momentum.

Second, there seems to be a measurement issue in ICT investment statistics. The possibility that cloud service providers assemble ICT equipment on an own-account basis may explain why

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Canada increased by 10.2 per cent per year during 1976-1981 and 1.2 per cent per year during 1981-1989. In the United States, it declined (-1.6 per cent per year during 1970-1981 and -4.0 per cent per year during 1981-1989). Thus, the real growth rates are higher than the nominal growth rates during the 1970s and 1980s. For the period after 2000, both countries experienced declining ICT prices but the United States experienced more rapidly declining ICT prices. This results in a larger difference between nominal and real growth rates in the United States compared to than in Canada. See Thomas (2015) and Thomas (2016) for detail.

[3]Prior to the introduction of cloud computing, most firms had to install servers and storage devices separately for each system and each department. Due to differences in servers' busy and idle periods and in system life cycles, a firm's average utilization of resources (*e.g.* servers) was often very low. According to Kuwazu (2015), the average utilization of servers among Japanese firms without a cloud system is estimated to be less than 30 per cent. Migration to cloud-based infrastructure would shift conventional IT tasks to the cloud that is more efficient.

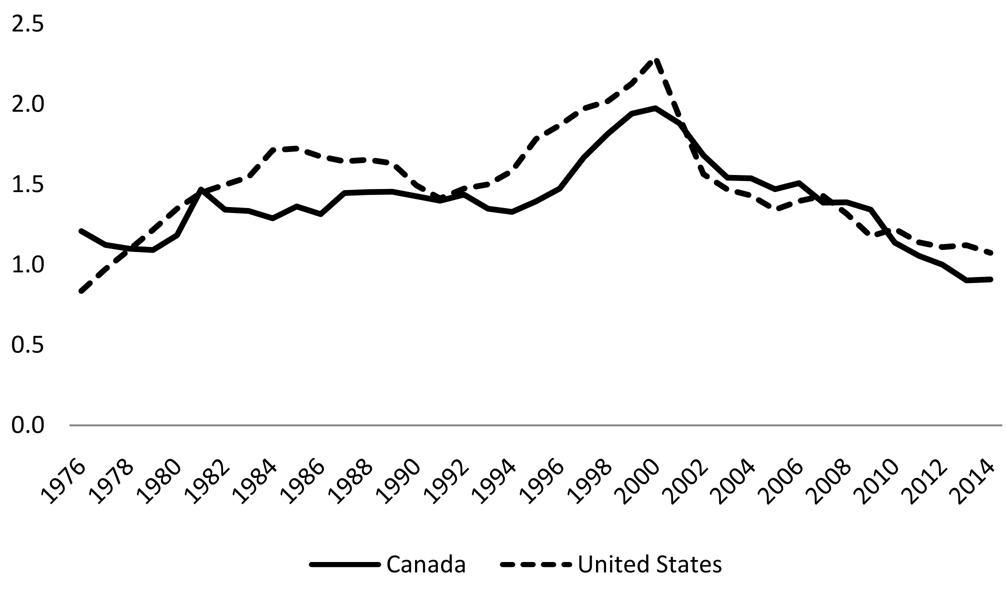
[4] This is based on the survey conducted by Spiceworks, a professional network for IT. It is also found that 30 per cent of organizations in North America expect more than half of their IT services to be cloud-based in two to three years. See "The annual report on IT budgets and tech trends" at https://www.spiceworks.com/marketing/state-of-it/report/

rapidly expanding capital expenditure (as reflected in their financial statement) does not translate into strong investment in ICT equipment statistics. For example, data from financial filings reveal that capital expenditure by big cloud service providers- "hyperscale" data centre operators - rose at an annual rate of 17 per cent over the 2010-2015 period reaching $50 billion USD by 2015 (see Byrne, Corrado, and Sichel, 2017a,b). It could be the case that a large portion of the capital expenditure has been on components used for own-account investment in ICT equipment not on already assembled IT equipment.

Some non-market production is included in the official statistics. For example, own-account software production (produced within establishments for internal use) is explicitly included as "own-account software investment" in the United States and "Own-account software design and development services" in Canada. However, it is unclear whether own-account ICT equipment is included. For example, the questionnaire for the business survey conducted by Statistics Canada does not contain any question regarding own-account capital and infrastructure investment.

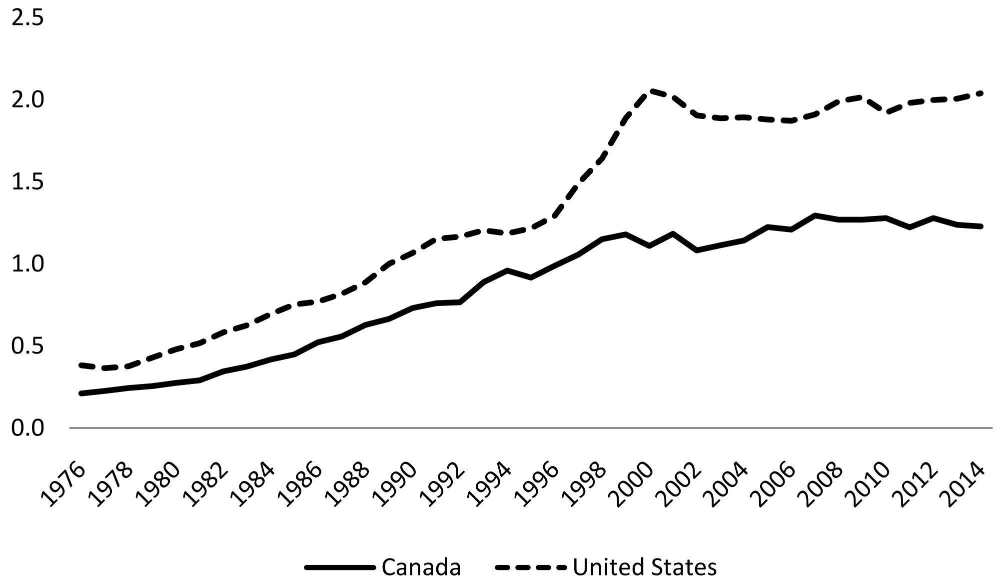
Indeed, investment in ICT equipment reflected in official statistics has been weak in both countries. The share of investment in ICT equipment in GDP has been on a downward trend since the early 2000s (see Chart 2). Although the share of investment in software and databases in GDP has not been on a downward trajectory, it has been nearly flat since the early 2000s (Chart 3).

Chart 2: Nominal investment in IT equipment as a share of nominal GDP, total economy, Canada and the United States, per cent, 1976-2014



Source: CSLS database for ICT investment. Available at http://www.csls.ca/data/ict.asp

Chart 3: Nominal investment in Computer Software and Databases as a share of nomial GDP, total economy, Canada and the United States, per cent, 1976-2014



Source: CSLS database for ICT investment. Available at http://www.csls.ca/data/ict.asp

To address the importance of the two issues, we attempt to quantify the amount of spending related to cloud computing not captured in the official statistics in Canada and the United States. Since official data related to cloud computing are very limited, we carry out our analysis using a set of data from multiple sources.

First, we rely heavily on the input-output tables available from Statistics Canada and the Bureau of Economic Analysis. We also use data produced by private consultancies and research firms as a reference to which we compare our estimates. The aim of this quantitative analysis is to capture the changing ICT investment pattern spurred by cloud computing within a scope of currently available data. We suggest that the readers view our estimates cautiously by taking them as rough guidance.

Based on a simple counterfactual analysis, we estimate that the purchase of cloud services ranges from $448 million CAD to $497 million CAD in 2006. By 2014, it ranges from $2,554 million CAD to $2,660 million CAD, with an annual growth rate of 23.3 per cent to 25.3 per cent over the 2006-2014 period. For the United States, our estimates suggest that the purchase of cloud services ranges from $32.1 billion USD to $36.1 billion USD in 2014, up from $7.3 billion USD and $10.5 billion USD in 2006. This implies that the annual growth rate is between 19.7 per cent and 23.7 per cent over the 2006-2014 period. This indicates that a quite significant amount of resources has been reallocated from ICT capital goods to purchasing ICT services.

In return, cloud service providers now purchase a substantial amount of ICT capital goods as they build cloud-based infrastructures. However, they are also building ICT equipment internally. To address this second issue, we adopt a simple approach introduced in Byrne, Corrado, and Sichel (2017a) to estimate the amount of own-account investment in IT equipment by cloud service providers. The approach is motivated by the fact that the IT service sector (which presumably covers all core activities of cloud service providers) purchases a large amount of computer and electronic parts and products but produced nearly zero output using these inputs. This suggests that these intermediates are used for own-account investment.

Our estimates indicate that if own-account investment in ICT equipment were included in the official ICT investment statistics, the investment in ICT equipment in Canada would have grown by 3.81 percentage points more per year over the 2006-2014 period. In terms of a share in nominal GDP, adding own-account investment in ICT equipment results in stabilization of the share instead of falling. From 1.47 per cent in 2005, the share falls to 1.42 per cent instead of 0.91 per cent in 2014. In the United States, adding own-account investment would lead to additional 3.12 percentage points annual growth rate over the 2006-2014 period. In terms of a share of GDP, it results in an upward trend instead of a downward trend as reflected in the official statistics. By 2014, the share recovers to 1.69 per cent for the share from 1.34 per cent in 2005 instead of falling to 1.07 per cent.

The key takeaway from our estimates is that the role of cloud computing is potentially substantial in driving the ICT investment statistics in Canada and the United States. However, there is a great deal of lag for official statistics to reflect an increasing role of cloud computing in changing the ICT spending pattern. Hence, it is important to develop official statistics for cloud services and the cloud services sector so that we have a better understanding of the changing ICT spending pattern and its impact on ICT investment.

We emphasize that this report is an exploratory work to shed light on the impact of the changing ICT spending pattern on ICT investment by providing rough estimates of the role played by cloud computing. A primary goal of this report is to provide a broad picture of the changing ICT spending pattern driven by a rise of cloud computing and to promote further debate on the issue among statistics officials and researchers.

The rest of the report is organized as follows. The following section discusses definitions of cloud computing. It also summarizes key trends in North American cloud computing markets. Section III and Section IV present our quantitative analysis on the two issues for Canada and the United States. Section V discuss the impact of own-account investment on a general trend of ICT investment in the two countries. Section VI concludes.

II. Cloud Computing

A. Definition and service/deployment models of cloud computing

In this section, we discuss some key definitions and features of cloud computing. We start with the definition of cloud computing. The National Institute of Standards and Technology (NIST) first created a definition of cloud computing in 2009 and officially published it in 2011 after consultations with industry and government experts and stakeholders (Mell and Grance, 2011). NIST defines cloud computing as follows (Mell and Grance, 2011:2):

> Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort of service provider interaction.

The first milestone in cloud computing history was the emergence of Salesforce, an IT service firm in 1999. It introduced the concept of delivering enterprise applications through a simple website. Such a move paved the way for software firms to deliver their applications using the internet. In 2001, Amazon introduced Amazon Web Services to provide cloud-based services such as data storage, computation and human intelligence via the Amazon Mechanical Turk.

Subsequently, in 2006, Amazon launched Elastic Compute cloud (EC2), which was a commercial web service that allowed small companies and individuals to rent computers. It was the first widely accessible cloud infrastructure service. Following the introduction of EC2, Google and Microsoft subsequently launched more advanced cloud computing infrastructures. With the advent of more reliable cloud computing infrastructures during the mid 2000s, commercial cloud services started to take off. A significant number of firms (93 per cent of the firms in North America) now access computing resources through cloud services available in three main product classes.

The NIST definition includes a description of cloud service models or "product classes" (Mell and Grance, 2011:2.3):

- **Software as a Service (SaaS):** The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through either a thin client interface, such as a web browser (*e.g.,* web-based email), or a program interface. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user specific application configuration settings.

- **Platform as a Service (PaaS):** The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, services, and tools supported by the provider. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly configuration settings for the application-hosting environment.

- **Infrastructure as a Service (IaaS):** The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, and deployed applications; and possibly limited control of select networking components (e.g., host firewalls).

The service models highlighted above are distinct in the sense that cloud users can abstract from (or ignore) the underlying infrastructure in a varying degree. For IaaS, the user needs to think about not only the deployed application but also underlying operating systems and storage. On the other hand, the user of PaaS need to think about only the deployed application ignoring other aspects of the infrastructure. Finally, the SaaS user simply uses the deployed application without any control over it (*e.g*. its configuration settings).

Next, there are four distinct models of service deployment. According to NIST (Mell and Grance, 2011:3), they are:

1. **Private cloud:** The cloud infrastructure is provisioned for exclusive use by a single organization comprising multiple consumers (e.g., business units).It may exist on or off premises.

2. **Community cloud:** The cloud infrastructure is provisioned for exclusive use by a specific community of consumers from organizations that have shared concerns; it may exist on or off premises.

3. **Public cloud:** The cloud infrastructure is provisioned for open use by the general public; it exists on the premises of the cloud provider.

4. **Hybrid cloud:** The cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability (*e.g.*, cloud bursting for load balancing between clouds).

The private cloud is a form of an internal cloud maintained on a firm's intranet or data centre. This can be a great option for firms who already have established data centres or those concerned with security (*e.g*. government agencies, financial institutions, large-size corporations). However, with the private cloud, the user is responsible for all management, maintenance and updating of data centers. Moreover, it is expected that servers will need to be replaced after their life cycle, which can be very expensive.

The public cloud has advantages in terms of costs - no need to purchase hardware or software; maintenance –the service provider provides maintenance; and scalability - near-unlimited scale with on-demand resources to meet business needs. With the advantages of both deployment models, the hybrid cloud dominates enterprise cloud strategies (IDC, 2015). With the hybrid cloud, users can move between public and private deployment options for their operation depending on their needs.

Finally, NIST also describes the infrastructure that underlies cloud computing as the following (Mell and Grance, 2011:2):

> A cloud infrastructure is the collection of hardware and software that enables the five essential characteristics of cloud computing. The cloud infrastructure can be viewed as containing both a physical layer and an abstraction layer. The physical layer consists of the hardware resources that are necessary to support the cloud services being provided, and typically includes server, storage and network components. The abstraction layer consists of the software deployed across the physical layer, which manifests the essential cloud characteristics. Conceptually the abstraction layer sits above the physical layer.

In summary, a core advantage of cloud computing is that organizations can substantially reduce their IT spending by shifting conventional IT tasks to the cloud that is much cheaper and more efficient (*i.e.* a higher utilization rate of existing IT resources). Cloud computing brings natural economies of scale. A cloud service provider's computing resources are pooled to serve many customers based on a multi-tenant model with different physical and virtual resources dynamically assigned and reassigned depending on customers' demand. Customers can easily scale up or down to meet their real-time demand for computing resources with a cloud system automatically controls and optimizes resource use by leveraging a metering capability (on a pay-per-use or charge-per-use basis).

These features of cloud computing imply lower unit costs for computing resources. Hence, every dollar decrease in IT budget spent on conventional computing services and related ICT capital goods would lead to a less-than-a-dollar increase in the budget spent on cloud services for a given amount of IT operation. Organizations can expand their IT operation with cheaper computing resources or less binding IT budget constraint (in real terms).[5]

B. Cloud market in North America and related IT spending patterns

Cloud computing is a fast-changing market characterized by very limited publicly accessible data. There are no predetermined metrics we can use to assess all aspects of the cloud market. Therefore, we summarize some important trends in cloud computing in North America based on

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[5] A given amount of cloud computing resources results in larger output since it leads to a higher utilization rate. For example, different departments within a firm can be free from the inefficiency due to the difference between servers' busy and idle periods. Cloud computing solves this problem by optimally assigning resources among those departments depending on the usage.

multiple studies and surveys done by various research and consulting firms. We are unlikely to perfectly capture every facet of the cloud market. However, we think our review is still useful background that motivates our quantitative analysis in the following sections.

The cloud in different markets has developed in varying ways due to factors such as market maturity, cultural preferences, and available infrastructure. Being a more mature market with advanced network infrastructures, firms in North American were able to quickly obtain access to large, state-of-the-art, centralized data centres that offered cloud services. The diffusion of cloud computing in North America has also been facilitated by the high-quality delivery infrastructure and the relatively short distance between users and data centres/service providers. Users were assured of reliable performance.

1. Service deployment models

North American firms are in a more favourable situation to adopt public cloud as a deployment model than firms in other markets (IDC, 2015). Cloud markets in emerging economies did not have a comparable network coverage or quality to support use of public cloud services. As a result, private cloud or hosted private cloud services became the preferred model of deployment in those markets. This trend was also driven by long-held cultural preferences for IT asset ownership and management of the IT systems by the enterprise itself (IDC, 2015).

Although hybrid cloud is still an important strategy for organizations adopting cloud due mainly to security concerns, there are a number of signs that firms are increasing the share of public cloud in their IT activities. This is mainly driven by "the growing understanding that cloud vendors offer state of-the-art security; the innovative security-related services actually being marketed by those vendors; a gathering boom in value-added offerings available through public clouds; the popularity of “cloud first” approaches in procurement ecosystems; and greater overall trust in public clouds.", according to International Trade Administration of the U.S. Department of Commerce (ITA, 2016:7).

Bain and Company, a consultancy, also found that while security remains as a major concern inhibiting large firms from adopting the public cloud, that concern has lessened with the emergence of new considerations such as compliance, vendor lock-in, and data portability (Bain and Company, 2017).The survey by Spiceworks, a professional network for IT, supports this finding. According to them, in North America, large firms are planning to allocate as large a share of their IT budget to cloud services as smaller firms. For example, firms with 1,000-4,999 employees are allocating 31 per cent of the total IT budget on cloud services on average. This is comparable to the range of 31per cent to 33 per cent found for smaller-sized firms (*e.g.* 1-99, 100-499, 500-999 employees).

As firms gain maturity and familiarity in the usage of cloud computing over time, public cloud services are likely to play an even more important role than they do today. The International Trade Administration predicted that spending on public cloud expenditure will grow six times as quickly as overall IT spending over the 2013-2018 period, reaching $127 billion by 2018 (ITA, 2016). According to the IDC World Semiannual Public Cloud Services

Spending Guide released in 2018, worldwide spending on public cloud computing is expected reach $277 billion USD by 2021, achieving a compound annual growth rate of 21.9 per cent over their forecast horizon (2016-2021).[6] The United States is expected to account for 60 per cent of worldwide spending throughout the forecast (roughly $166 billion USD in 2021). Lastly, spending on public cloud in Canada reached $2.3 billion CAD in 2015 and is expected to double by 2020 reaching $5.5 billion CAD (IDC, 2016).

On the other hand, we expect that the role of the private cloud in driving the total demand for cloud services is likely to shrink due to its disadvantage in terms of cost and maintenance effort. For example, according to Wikibon, an IT research firm, the share of private cloud in the total revenue of Amazon Web Services is expected to decline over the next two decades.[7] The share of private cloud services accounted for only a small share of the total global cloud IT market revenue in 2015 and is projected to remain so over the next 5 years (Bain and Company, 2017).

Trends in the adoption of different service deployment models have important implications for the pattern in ICT investment in cloud computing. Cloud users opting for the public cloud do not undertake IT equipment/software investment directly for the purpose of accessing computing resources. On the other hand, those adopting the private cloud may have to purchase related IT equipment/software in order to set up private cloud infrastructures for exclusive use, ownership, and management of computing resources.

Based on the trend that cloud services are increasingly delivered via the public cloud, we believe that the amount of ICT investment related to cloud computing in the private sector (net of cloud service providers) has been and will be shrinking. A significant portion of capital expenditure on accessing computing resources is likely to have been diverted to current expenditure on purchasing services.

Indeed, North American firms have increased their IT budget allocation for cloud services and plan to spend proportionally more than they do on software or hardware. According to the 2016 survey conducted by Spiceworks, on average, firms in North America plan to allocate 31 per cent of the total IT budget on cloud services in 2018.[8] This is higher than the 22 per cent and 26 per cent of their 2018 IT budget allocated to hardware and software, respectively.

2. Service models

Most of the cloud services used by organizations are in the form of Software as a Service (SaaS). According to the joint research done by IDC and Canadian Channel Chiefs Council, a non-profit IT group, 9.7 per cent and 12.2 per cent of the total IT spending in 2016 was spent on

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[6] IDC has continued to revise upwardly its forecast for spending on the public cloud. In their 2017 release, they forecasted that spending on the public cloud would reach $266 billion USD in 2021 achieving a five-year compound annual growth rate of 21.0% . The press releases of the forecast are available at https://www.idc.com/getdoc.jsp?containerId=prUS43511618 and https://www.idc.com/getdoc.jsp?containerId=prUS42889917&pageType=PRINTFRIENDLY

[7] See "How Big can Amazon Web Services get?" at https://siliconangle.com/blog/2017/02/20/wikibon-report-preview-big-can-amazon-web-services-get/

[8] The survey is available at https://www.spiceworks.com/marketing/state-of-it/report

SaaS in Canada and the United States, respectively (Canadian Channel Chiefs Council, 2017).These are much higher than 1.7 per cent and 1.4 per cent spent on IaaS or 1.1 per cent and 1.7 per cent on PaaS in Canada and the United States, respectively.

This pattern is not limited to Canada and the United States. According to Bain and Company (2017), among all cloud product classes, SaaS accounted for the largest share of the global cloud IT market revenue in 2015 and it is projected to remain so over the next decade. IDC also predicts that SaaS will continue to be the largest cloud computing category, accounting for nearly two thirds of all public cloud spending in 2018.

SaaS consists of applications and system infrastructure software. Spending on SaaS tends to be dominated by applications purchases. Among the SaaS applications, IDC predicts that enterprise resource management (ERM) applications and customer relationship management (CRM) applications will account for the largest SaaS spending in 2018, followed by collaborative applications and content applications.[9]

Although Platform as a Service (PaaS) accounts for a small share of public cloud spending, its share is expected to increase substantially in the near future. According to KPMG, while spending on SaaS and IaaS will continue to increase, "spending on PaaS will increase significantly as chief information officers (CIO's) adopt cloud computing as their strategic development and production platform for both new applications and services, and as they begin the process of paying down technical debt and migrating or modernizing their legacy IT estate" (KPMG, 2016:2).IDC also predicts that PaaS spending will exhibit the fastest growth over their projection horizon (2016-2021).[10]

3. Cloud infrastructure investment

Most of the investment in cloud infrastructures is done by cloud service providers. Since the mid-2000s, cloud service providers have invested heavily in cloud infrastructures. Accordingly, their capital expenditure has increased significantly over the past years. The financial filings of large cloud service providers or "hyperscale" data centre operators reveal that they spent more than $50 billion USD worldwide as capital expenditure in 2015 (Byrne*et al*., 2017a).[11] This is the result of an annual growth rate of 17 per cent in their capital expenditure over the 2010-2015 period.

Importantly, as commercial cloud services started to take off in North America since the mid-2000s, the cloud model has rapidly dominated the data centre market as well. According to Kuwazu (2015), in North America, server shipments to data centres (or cloud vendors) already

[9] Although SaaS has been and will be the most common cloud service model, it may not be straightforward to categorize it as a cloud service. For example, Byrne *et al.* (2017a) treat SaaS as a category of software product services rather than cloud services per se, thereby excluding SaaS in their analysis. We discuss this issue in more details in the following section.

[10] See "Worldwide Public Cloud Services Spending Forecast to Reach $160 Billion This Year, According to IDC" at https://www.idc.com/getdoc.jsp?containerId=prUS43511618

[11]Hyperscale is the terms used to describe a data centre operator whose revenue is at least $1 billion USD in IaaS/PaaS or $2 billion USD in SaaS or $4 billion USD from internet/search/social networking or $8 billion USD from e-commerce/payment processing.

exceeded those to end-user as of 2010. Cloud service providers now account for 90 percent of data centre traffic and accounted for essentially all growth in traffic since 2010 (Byrne *et al*., 2017a).

This implies that server business models have been changing. The conventional flow of "server manufacturer → distributor and system integrators→ end users" is changing to "server manufacturers → cloud service providers". End users are now paying cloud service providers rather than directly buying servers. As a result, the server manufacturers are tailoring matters related to product development, sales, product specifications, and marketing for cloud service providers rather than for end users. According to Kuwazu (2015), in North America, nearly 70 percent of server shipments go to cloud service providers. Server shipments per order have grown to be considerably larger than those for orders issued from end users to distributors.

The practice of end-user companies individually establishing servers has become marginal. There is a trend towards server manufacturers producing servers as "white boxes" without a manufacturer's brand name and in "designating optimal specifications". As a result, servers have become very similar to manufacturing equipment for factories rather than office equipment. Moreover, some of North America's major cloud providers are placing large volume orders directly with electronic component producers (*e.g.* electronic manufacturing services) bypassing server manufacturers (Kuwazu, 2015). This implies that they are producing ICT equipment on an own-account basis. As a result, the role of equipment manufactures in producing servers has been rapidly shrinking.

For example, Google and Facebook now design electronics components to be produced by manufacturers for their data centers (*e.g.* servers, network switches, and data storage devices).[12] According to Byrne, Corrado, and Sichel (2017b: footnote 6), "some major cloud providers commonly have those designs fabricated under contract by other companies, but add software essential to the operation of the device within the data center. Under this arrangement, the output of the contract manufacturer would be recorded as electronic components (*e.g.* circuit boards), rather than final electronics and would be recorded as intermediate inputs in the Bureau of Economic Analysis input-output tables, rather than investment".

In summary, we have identified two important facets of the changing ICT spending pattern. First, it is increasingly common for organizations to purchase services from cloud providers instead of purchasing related capital from equipment manufacturers. In this case, resources previously used for investment to access computing are diverted to purchasing services (*e.g.* SaaS, IaaS, and PaaS) from cloud vendors. Organizations opting for the private cloud could invest in cloud infrastructures by ordering products from distributors as final demand. However, this will be reflected in official statistics for ICT investment. Second, most of the investment in cloud-related capital is likely to be carried out by cloud vendors either by purchasing already-assembled equipment directly from server manufacturers or by own-account investment. Official statistics would be underestimated by the amount of own-account investment.

[12]See "Facebook and Google Try Self Help," at https://www.wsj.com/articles/facebook-and-google-try-self-help-1377460750

III. Issue One: Resources diverted from ICT investment to purchasing cloud services.

As highlighted in the previous section, with an increased use of cloud services, the focus of ICT spending by firms has shifted away from equipment to services. An obvious first-order impact of the shift would be a decline in the demand for ICT investment goods. For a given level of ICT services, the demand for ICT equipment is likely to have declined as firms use cloud services as a substitute for ICT equipment and as cloud service providers can produce more computing services with a given unit of ICT capital goods (*i.e.* they are more efficient).We conjecture that this phenomenon could partly explain the weak ICT investment as reflected in official statistics in Canada and the United States.

In this section, we attempt to quantify the value of the purchase of cloud services in Canada and the United States over the period 2006-2014. This is to demonstrate an important facet of the changing ICT spending pattern driven by cloud computing: the reallocation of resources to purchasing computing services. The purchase of cloud services by firms is not counted as ICT investment but as a purchase of intermediate inputs. Therefore, one way to assess the impact of cloud adoption on ICT investment statistics is to examine trends in intermediate services supplied by cloud service producers to cloud service users. For this we turn to the input-output tables published by Statistics Canada and the Bureau of Economic Analysis.

A. Proxy for the purchase of cloud services

Unfortunately, official data for spending on cloud services are not available in Canada and the United States. Hence, we focus on the commodity category under which cloud services are classified. Following Byrne *et al.* (2017a), we choose the intermediate purchase of data processing, hosting, and related services as a (imperfect) proxy for the purchase of cloud services in the economy. We recognize that it is an imperfect proxy since it includes not only cloud computing but also traditional computing services.

Data processing, hosting, and related services is categorized under Input-Output Commodity Classification code MPS518 for Canada and BEA Input-Output commodity Code 512 for the United States. In Canada, Input-Output Commodity Classification (IOCC) is based on North American Product Classification System (NAPCS). In NAPCS, data processing, hosting, and related services (NAPCS code 75111) includes: website hosting and domain name registration services (NAPCS 751111); application service provisioning (NAPCS 751112); business process management services (NAPCS 751113); other information technology infrastructure provisioning services (NAPCS 751114); information technology infrastructure and network management services (NAPCS 751115); and information and document transformation services (NAPCS 751116).

Among these sub-categories, cloud services are classified under application service provisioning (NAPCS 751112) and other information technology infrastructure provisioning services (NAPCS 751114). First, application service provisioning (NAPCS 751112) represents

"Provision of leased software applications from a centralized, hosted, and managed computing environment, customized to the needs of individual clients". The definition includes software delivered via cloud from cloud service providers (*i.e.* SaaS). Moreover, from NAPCS 2017, SaaS is assigned a code: Software as a service, on cloud (NAPCS 7511122).[13] Other information technology infrastructure provisioning services (NAPCS 751114) includes Data storage infrastructure provisioning services (NAPCS 751142). From NAPCS 2012, "cloud storage services" is explicitly listed as an illustrative example for this category.

Statistics Canada started to explicitly include some cloud services in its commodity classification from 2012. By definition, however, cloud services were still categorized under data processing, hosting, and related services prior to NAPCS 2012. Prior to NAPCS 2012, the survey respondent firms producing the data processing, hosting, and related services were asked to complete the question in the same characteristics cell as they do after NAPCS 2012.[14] Hence, data processing, hosting, and related services is still a valid proxy for the period prior to 2012.

Using this proxy, we attempt to estimate the amount explained by cloud computing based on a counterfactual analysis. Specifically, we estimate the intermediate purchase of the service in addition to what would have been purchased in the world of no cloud computing. We attribute this quantity to the adoption of cloud computing.

As highlighted in the previous section, SaaS has been the most common cloud service model. Hence, a significant portion of the purchase of cloud service in the economy would represent the purchase of SaaS. Yet, Byrne *et al.* (2017a) argue that SaaS is best understood as a category of software product services rather than cloud services per se. So it should be regarded as software products sold via an online subscription business model. Consequently, they exclude SaaS from their analysis on cloud computing.

It is debatable whether or not SaaS should be categorized as cloud services. In this report, we do not exclude SaaS for two reasons. First, we follow the NIST definition that SaaS is one of the product classes of the cloud. Second, we cannot explicitly exclude SaaS due to data limitations even if we opted for exclusion. Data processing, hosting, and related services includes not only SaaS but also other services such as traditional data centres. Since it is the most detailed classification available to us, we cannot differentiate the individual components.

B. Trends in the intermediate purchase of data processing, hosting, and related services in Canada and the United States

Table 2 presents the intermediate purchase of data processing, hosting, and related services (by all industries) for Canada over the period 1997-2014. We observe that the purchase of the services shows a clear upward trend over the period. It increased from $2,241 million CAD in 1997 to $8,919 million CAD in 2014, an annual growth rate of 8.47 per cent.

[13] However, this individual category is not available in the input-output tables published by Statistics Canada.
[14] This information was provided by an official at the Consumer and Business Services Surveys Division, Statistics Canada.

However, the upward trend may in part reflect a growing size of the economy over time. Hence, we focus on the "intensity" of the intermediate purchase of data processing, hosting, and related services (defined as per cent of GDP). Here, we observe that the intensity has increased over time. The intermediate purchase of the service accounted for 0.25 per cent of GDP in 1997. The intensity had increased over time reaching 0.45 per cent in 2014.

Table 2: Intermediate purchase of data processing, hosting, and related services (I-O commodity code MPS 518), basic price, Canada, millions of CAD, 1997-2014

Year	Total	Pvt	Govt	GDP	% GDP, total	% GDP, pvt	% GDP, govt
1997	2,244	2,035	206	882,734	0.25	0.23	0.02
1998	2,552	2,295	253	914,974	0.28	0.25	0.03
1999	2,735	2,550	180	982,444	0.28	0.26	0.02
2000	2,946	2,743	196	1,076,577	0.27	0.25	0.02
2001	3,180	2,865	307	1,108,047	0.29	0.26	0.03
2002	3,582	3,228	346	1,152,905	0.31	0.28	0.03
2003	4,150	3,820	322	1,213,175	0.34	0.31	0.03
2004	4,641	4,302	335	1,290,907	0.36	0.33	0.03
2005	4,835	4,470	361	1,373,853	0.35	0.33	0.03
2006	5,073	4,723	346	1,450,404	0.35	0.33	0.02
2007	5,875	5,501	369	1,529,589	0.38	0.36	0.02
2008	6,097	5,704	388	1,603,416	0.38	0.36	0.02
2009	6,034	5,377	650	1,567,007	0.39	0.34	0.04
2010	6,440	5,775	655	1,662,131	0.39	0.35	0.04
2011	7,124	6,435	674	1,769,922	0.40	0.36	0.04
2012	7,400	6,683	705	1,822,808	0.41	0.37	0.04
2013	8,110	7,280	811	1,897,532	0.43	0.38	0.04
2014	8,939	8,060	859	1,990,180	0.45	0.40	0.04

Note: The title of MPS 518 changes over time. We use the most recent title in this table.
Source: CANSIM Table 381-0033 and input-output tables published by Statistics Canada (Catalogue 15F0041X).

Table 3 reports the intermediate purchase of data processing, hosting, and related services for the United States over the period 1997-2016. We observe a strong upward trend over the period increasing from $43.7 billion USD in 1997 to $148.5 billion USD in 2016. Similarly, the intensity of the purchase of computing services increased over time. In 1997, the intermediate purchase accounted for 0.51 per cent of GDP. As of 2016, it reached 0.80 per cent.

Interestingly, the share for the government sector is considerably higher in the United States. Throughout 1997-2014, the average share for the government is 0.18 per cent in the United States while it stands at 0.02 per cent in Canada (see Table 4). This implies that nearly half of the difference in the intensity between the United States and Canada is attributed to the difference in the share of government.

Table 3: Intermediate purchase of data processing, hosting, and related services (BEA Input-Output commodity Code 512), producers' price, the United States, billions of USD, 1997-2016

Year	Total	Pvt	Govt	GDP	% GDP, total	% GDP, pvt	% GDP, govt
1997	44.2	32.7	11.0	8,608.50	0.51	0.39	0.13
1998	48.4	37.3	10.6	9,089.20	0.53	0.42	0.12
1999	56.1	42.3	12.6	9,660.60	0.58	0.45	0.13
2000	63.6	48.2	13.8	10,284.80	0.62	0.48	0.13
2001	65.9	48.1	16.5	10,621.80	0.62	0.47	0.15
2002	66.4	46.3	19.3	10,977.50	0.60	0.43	0.18
2003	68.9	48	20.0	11,510.70	0.60	0.42	0.17
2004	75.6	52.7	22.0	12,274.90	0.62	0.44	0.18
2005	80.7	56.5	23.2	13,093.70	0.62	0.44	0.18
2006	92.1	65.1	25.7	13,855.90	0.66	0.48	0.19
2007	102.6	74.6	25.7	14,477.60	0.71	0.53	0.18
2008	109.8	78.5	28.8	14,718.60	0.75	0.55	0.20
2009	107.9	69.4	35.8	14,418.70	0.75	0.50	0.25
2010	112.7	72.6	37.5	14,964.40	0.75	0.50	0.25
2011	120.4	80.9	36.2	14,964.40	0.80	0.56	0.24
2012	127.2	85.5	37.1	16,155.30	0.79	0.56	0.23
2013	132.8	96.4	31.8	16,691.50	0.80	0.60	0.19
2014	138.8	102.4	31.7	17,427.60	0.80	0.61	0.18
2015	147.9	106.9	36	18,120.70	0.82	0.62	0.20
2016	153.8	111.1	37.4	18,624.50	0.83	0.62	0.20

Source: Input-output tables published by Bureau of Economic Analysis

Table 4: Average intensity of industries' purchase of data processing, hosting, and related services (as average % GDP), all industries, Canada and the United States, per cent

	Canada			United States		
Period	Total	Private Sector	Government	Total	Private Sector	Government
1997-2014	0.35	0.32	0.03	0.69	0.50	0.18
1997-1999	0.27	0.25	0.02	0.54	0.42	0.12
1997-2005	0.32	0.29	0.02	0.59	0.44	0.15
2000-2005	0.32	0.30	0.03	0.61	0.45	0.17
2006-2014	0.40	0.36	0.04	0.77	0.56	0.21
2006-2007	0.37	0.34	0.02	0.69	0.51	0.18
2008-2009	0.38	0.35	0.03	0.75	0.53	0.22
2010-2014	0.41	0.37	0.04	0.79	0.57	0.22

Note: Data processing, hosting, and related services is categorized under Input-Output Commodity Classification code MPS518 for Canada and BEA Input-Output commodity Code 512 for the United States.
Source: Table 1 and Table 2

We pay particular attention to 2006, the year in which Amazon launched Elastic Compute cloud (EC2), the first widely accessible cloud infrastructure services. Since the introduction of EC2, cloud computing took off in the economy as Google and Microsoft subsequently launched more advanced cloud computing infrastructures. Thus, we suggest the structural break in accessing computing resources occurred in 2006.

Table 4 shows the average intensity of the intermediate purchase in Canada and the United States over selected sub-periods. In general, the average intensity prior to 2006 is notably lower than that observed during the period after 2006. Any sub-period before 2006 exhibits an average intensity that is clearly lower than that observed during a sub-period after 2006.[15]

For example, in the United States, the average intensity ranges from 0.54 per cent to 0.59 per cent during the sub-periods before 2006. The average intensity reaches as high as 0.77 per cent during the 2006-2014 period, the period associated with a wide diffusion of cloud computing. In Canada, the average intensity stands at 0.27 per cent to 0.32 per cent during the sub-periods before 2006. The average intensity reaches 0.40 per cent during the 2006-2014 period.

Although the average intensity tends to be higher during the period after 2006, the growth of the intermediate purchase of data processing, hosting, and related services somewhat slows after 2006. Table 5 summarizes the annual growth rate observed during selected sub-periods. Over the 2000-2006 period, purchases grew at an annual rate of 9.48 per cent and 6.36 per cent in Canada and the United States, respectively. However, the growth rate decreases to 7.34 per cent and 5.26 per cent in each country respectively over the 2006-2014 period.

Table 5: Annualized growth rates of the purchase of data processing, hosting, and related services, total economy, Canada and the United States

	Canada			United States		
Period	Total	Pvt	Govt	Total	Pvt	Govt
1997-2014	8.47	8.44	8.76	6.96	7.13	6.42
1997-2006	9.49	9.80	5.93	8.49	7.99	9.89
2000-2006	9.48	9.45	9.94	6.36	4.91	10.90
2006-2014	7.34	6.93	12.04	5.26	6.16	2.64
2006-2007	15.81	16.48	6.65	11.39	15.83	-0.07
2007-2009	1.34	-1.11	32.72	2.54	-3.20	18.05
2009-2014	8.18	8.46	5.73	5.17	8.25	-2.42

Note: Data processing, hosting, and related services is categorized under Input-Output Commodity Classification code MPS518 for Canada and BEA Input-Output commodity Code 512 for the United States.
Source: Author's calculation based on Table 1 and 2.

[15] Obviously, this indicator is robust to cyclicality as it controls for GDP. As an example, one can see that the average intensity continues to increase over the course of the recession following the financial crisis in 2007.

The growth rate annualized over the period 2006-2014 is affected by the substantial fall in growth during the period following the financial crisis in 2007 (*i.e.* 2007-2009).[16] We see that the growth in the purchase of computing services was again robust after 2009 in Canada and the United States. For the United States, the annual growth in the private sector was actually higher after 2009 than during any sub-period before 2006.

It is true that when one takes a growth rate, it fluctuates (*i.e.* goes up and down) over time as we get to de-trend the time-series. However, it should be noted that a growth rate still tends to fall substantially during a recession. This affects the growth rate annualized over a period that includes the recession. Hence, annual growth rates would pick up not only the potential effect of cloud computing but also a cyclical component of the movement in the purchase of computing services.

Note also that data processing, hosting and related services include not only cloud services but also other types of computing service. Hence, the slower growth rate after 2006 may not necessarily be related to cloud services. We actually find evidence that the importance of cloud services in data processing, hosting, and related services has been increasing over time.

As we present in the following subsection in more detail, the share of "hosting and information technology infrastructure provisioning services" (*e.g.* SaaS, IaaS, and PaaS) in the total sales in data processing, hosting, and related services had increased over time (see Table 6). Over the same period, the shares of other service types had declined in general. Hence, the slower growth in the purchase of data processing, hosting, and related services might have been driven by other types of computing services (*e.g.* firms migrating from conventional computing to cloud computing).

The implication above suggests that a better indicator for the role of cloud computing is the average intensity of the purchase of computing services: it controls for GDP (see Table 4 for its robustness to cyclicality); and it better captures a general trend of the increasing role of cloud computing that emerged after 2006. As a result, we compute counterfactuals based on the average intensity in the following subsection.

C. Counterfactual Analysis

1. Methodology

In this subsection, we compute counterfactual levels of intermediate purchase that would have occurred had there been no wide spread of cloud computing. A key assumption is that any increase in the average intensity of the purchase in computing services after 2005 is driven by a diffusion of cloud computing.

[16] The fall in growth rate during the 2007-2009 period is the biggest drop observed in our sample period, 1997-2014. We do see a fall in annual growth rate following the burst of the dot com bubble but the extent is much smaller.

The counterfactual is computed over the period after 2006 assuming the average intensity observed during the period prior to 2006 (*i.e.* GDP multiplied by the average intensity):

$$P_t^c = GDP_t \cdot \overline{s_\tau}$$

where P_t^c indicates a counterfactual purchase of data processing, hosting, and related services in time t and $\overline{s_\tau}$ is the average intensity observed over sub-period, τ.

Here, we compute counterfactuals in two different scenarios: 1. counterfactuals assuming the average intensity observed during 1997-2005; and 2.counterfactuals assuming the average intensity observed during 2000-2005. Obviously, the counterfactual would be higher under scenario 2 which uses the average intensity observed during the period closest to 2006-2014. We believe that counterfactual 2 is likely to present a more realistic estimate as it is based on the period that covers a more relevant phase of the digitalization of the economy but without a wide spread of cloud computing (*i.e.* 2000-2005).

Finally, we estimate the purchase of cloud services by taking the difference between the actual and counterfactual level of the purchase ($P_t - P_t^c$). Again, this implies that we assume additional purchase of data processing, hosting, and related services after 2005 is completely driven by a rise of cloud computing (net of the effect of a growing economy).

We argue that this is a plausible assumption since cloud computing is the most important IT development during the mid 2000s. To support this, we refer to the Annual Survey of Software Development and Computer Services conducted by Statistics Canada. The survey has information for the breakdown of the total sales in the NAICS industry, data processing, hosting, and related services (NAICS 51821). The breakdown is by the type of computing services. Most relevant to our analysis is the "hosting and information technology infrastructure provisioning services" under which cloud services are classified (*i.e.* SaaS, PaaS, and IaaS).The category consists of application service provisioning (NAPCS 751112) and other information technology infrastructure provisioning services (NAPCS 751114). Hence, we believe that this category is a very close proxy for cloud services.

Table 6 reports the breakdown of the total sales in data processing, hosting, and related services in terms of a share (per cent). We find that the share of "hosting and information technology infrastructure provisioning services" increased over time while the aggregate share of other types of service tended to decline. The "hosting and information technology infrastructure provisioning services" accounted for 56.4 per cent of the total sales in 2008. It increased by 11.2 percentage points over the next 4 years to reach 67.6 per cent in 2012. Other types of service do not exhibit a clear upward trend in their share.[17]Although it is not possible to further breakdown

[17]It would be useful to compute the absolute level of sales in "hosting and information technology infrastructure provisioning services" using the shares provided in Table 6, the total purchase of data processing, hosting and related service (I-O commodity code MPS 518) given in Table 2, and the share of the total MPS 518 produced by the NAICS industry 51821 (data processing, hosting, and related services) in Canada. However, the two commodity categories are not perfectly comparable. Therefore, we do not attempt to impute the absolute level of the sales for the 2008-2012 period.

the category to cloud services, this trend supports our claim that the role of cloud computing in ICT spending has grown since the introduction of the first widely accessible cloud services in the mid 2000s.

Table 6: Breakdown of sales in Data processing, hosting, and related services (NAICS 51821) by type of services, per cent, 2008-2012

	Hosting and information technology infrastructure provisioning services	Network management services	Computer systems management services	Information and document transformation services	Computer systems design and related services	Software publishing	Other sales
2008	56.4	7.8	3.8	15.3	9.5	F	7.3
2009	59.3	2.3	1.7	15.0	13.8	F	10.5
2010	68.6	1.2	1.7	15.1	8.7	F	4.5
2011	65.6	1.2	2.2	11.4	11.8	F	7.4
2012	67.6	1.5	1.7	12.1	12.1	1.0	4.0

Note: F indicates that statistics is too unreliable to be published. The shares may not add up to 100.0 due to rounding errors. Data are also available for the 2013-2015 period (CANSIM Table 354-0012). Unfortunately, due to the changes made to the methods and processes used to compile statistics, the data for this period are not comparable to the data reported in Table 6 (This was part of the Integrated Business Statistics Program (IBSP) launched in 2013. See http://www.statcan.gc.ca/eng/dai/btd/ibsp for details). We find that, during 2013-2015 period, the share stabilizes: 43.2 per cent in 2013, 43.0 per cent in 2014, and 43.5 per cent in 2015. Again, the lower shares here do not mean that the share has decreased from the previous period. They are not comparable.
Source: Software Development and Computer Services published by Statistics Canada(Catalogue number 63-255-X).

Hence, it is reasonable to argue that cloud computing largely explains the increase in the average intensity of the purchase of computing services in the economy. Although we do not present comparable evidence for the United States, we argue that a similar trend would be found in that country since it has a cloud computing market of a size much bigger than that in Canada.[18] To check the extent our assumption is true, we also compare our estimates with cloud spending/revenue data from external sources in the following subsection.

2. Results for Canada and the United States

Table 7 reports our counterfactual levels of intermediate purchase of computer and electronics components in Canada over the 2006-2014. Had there been no wide diffusion of cloud computing in the economy, the upward trend in the purchase of computing services would have been much less pronounced after 2006 (see Appendix Chart A1). Instead of rising by $3,850 million CAD, the purchase would have increased by $1,703 million CAD under counterfactual 1 or $1,732 million CAD under counterfactual 2 over the 2006-2014 period. A similar trend is observed for the United States (Table 8 and Appendix Chart A2).

[18] For example, the United States accounts for over 60 per cent of the worldwide spending on the public cloud while Canada accounts for less than 4 per cent. For example, according to IDC, the worldwide spending reached $70 billion USD. In 2015, the spending in Canada stood at $2.3 billion CAD. See IDC (2016) and "Public Cloud Spending to Reach Nearly $70 Billion Worldwide in 2015, According to IDC" at https://www.businesswire.com/news/home/20150721005355/en/Public-Cloud-Spending-Reach-70-Billion-Worldwide.

Table 7: Counterfactual intermediate purchase of data processing, hosting, and related services (I-O commodity code MPS 518), basic prices, all industries, Canada, millions of CAD, 2006-2014

Year	Actual			Counterfactual 1			Counterfactual 2		
	Total	Private	Gov't	Total	Private	Gov't	Total	Private	Gov't
2006	5,073	4,727	346	4,576	4,217	359	4,653	4,279	374
2007	5,875	5,506	369	4,825	4,447	378	4,907	4,513	394
2008	6,097	5,709	388	5,058	4,662	396	5,144	4,731	413
2009	6,034	5,384	650	4,944	4,556	387	5,027	4,623	404
2010	6,440	5,785	655	5,244	4,833	411	5,332	4,904	429
2011	7,124	6,450	674	5,584	5,146	438	5,678	5,222	456
2012	7,400	6,695	705	5,750	5,300	451	5,848	5,378	470
2013	8,110	7,299	811	5,986	5,517	469	6,087	5,598	489
2014	8,939	8,080	859	6,279	5,786	492	6,385	5,872	513
	Annualized growth rates, %								
2006-2014	7.34	6.93	12.04	4.03	4.03	4.03	4.03	4.03	4.03

Note: Counterfactual 1 is based on the average % GDP observed during 1997-2005. Counterfactual 2 is based on the average % GDP observed during 2000-2005.
Source: Author's calculations based on CANSIM Table 381-0033 and input-output tables published by Statistics Canada (Catalogue 15F0041X).

Table 8: Counterfactual intermediate purchase of data processing, hosting, and related services (BEA Input-Output commodity Code 512), all industries, United States, billions of USD, 2006-2016

Year	Actual			Counterfactual 1			Counterfactual 2		
	Total	Private	Gov't	Total	Private	Gov't	Total	Private	Gov't
2006	92.1	66.4	25.7	81.6	60.5	21.1	84.8	61.8	23.0
2007	102.6	76.9	25.7	85.3	63.2	22.0	88.7	64.6	24.0
2008	109.8	81.0	28.8	86.7	64.3	22.4	90.1	65.7	24.4
2009	107.9	72.0	35.8	84.9	63.0	22.0	88.3	64.4	23.9
2010	112.7	75.3	37.5	88.1	65.3	22.8	91.6	66.8	24.8
2011	120.4	84.2	36.2	88.1	65.3	22.8	91.6	66.8	24.8
2012	127.2	90.1	37.1	95.1	70.5	24.6	98.9	72.1	26.8
2013	132.8	101.0	31.8	98.3	72.9	25.4	102.2	74.5	27.7
2014	138.8	107.1	31.7	102.6	76.1	26.5	106.7	77.8	28.9
2015	147.9	112.0	36.0	106.7	79.1	27.6	111.0	80.9	30.1
2016	153.8	116.4	37.4	109.7	81.3	28.4	114.0	83.1	30.9
	Annualized growth rates, %								
2006-2014	5.26	5.78	3.81	3.00	3.00	3.00	3.00	3.00	3.00

Note: Counterfactual 1 is based on the average % GDP observed during 1997-2005. Counterfactual 2 is based on the average % GDP observed during 2000-2005.
Source: Author's calculations based on input-output tables from the Bureau of Economic Analysis.

Our estimates of the purchase of cloud services (difference between actual and counterfactual) in Canada and the United States are reported in Table 9 and Table 10, respectively. For Canada, the estimated purchase of cloud services ranges from $420 million CAD (counterfactual 2) to $497 million CAD (counterfactual 1) in 2006 accounting for 8.3 per cent and 9.8 per cent of the actual purchase, respectively. The estimated purchase of cloud services increases over time in terms of both absolute and relative terms. By 2014, it reaches as much as $2,660 million CAD under counterfactual 1. This accounts for 29.8 per cent of the total purchase of computing services in 2014. Under counterfactual 2, the purchase of cloud services is estimated to be $2,554 million CAD in 2014 accounting for 28.6 per cent of the total purchase of computing services made in that year. This implies that, over the 2006-2014 period, the purchase of cloud services had increased at an annual rate of 23.3 per cent under counterfactual 1 and 25.3 per cent under counterfactual 2.

Table 9: Purchase of cloud computing proxied by the purchase of data processing, hosting, and related services (I-O commodity code MPS 518), Canada, 2006-2014

	Difference (Actual - Counterfactual), millions of CAD					
	Counterfactual 1			Counterfactual 2		
Year	Total	Private	Gov't	Total	Private	Gov't
2006	497	510	-	420	448	-
2007	1,050	1,059	-	968	993	-
2008	1,039	1,047	-	953	978	-
2009	1,090	828	263	1,007	761	246
2010	1,196	952	244	1,108	881	226
2011	1,540	1,304	236	1,446	1,228	218
2012	1,650	1,395	254	1,552	1,317	235
2013	2,124	1,782	342	2,023	1,701	322
2014	2,660	2,294	367	2,554	2,208	346

	Ratio of difference to actual purchase, %					
	Counterfactual 1			Counterfactual 32		
Year	Total	Private	Gov't	Total	Private	Gov't
2006	9.8	10.8	-	8.3	9.5	-
2007	17.9	19.2	-	16.5	18.0	-
2008	17.0	18.3	-	15.6	17.1	-
2009	18.1	15.4	40.4	16.7	14.1	37.8
2010	18.6	16.5	37.3	17.2	15.2	34.6
2011	21.6	20.2	35.1	20.3	19.0	32.3
2012	22.3	20.8	36.1	21.0	19.7	33.3
2013	26.2	24.4	42.1	24.9	23.3	39.7
2014	29.8	28.4	42.7	28.6	27.3	40.3

Note: Counterfactual 1 is based on the average % GDP observed during 1997-2005. Counterfactual 2 is based on the average % GDP observed during 2000-2005. Some negative values for the government sector are omitted (indicated by '-'). For 2006, 2007 and 2008, the intensity of the purchase of MPS 518 by government was smaller than the average intensity used to compute counterfactuals. Hence, the difference between the actual and counterfactual is negative.
Source: Table 7

For the United States, the estimate ranges from $7.3 billion USD to $10.5 billion USD in 2006 accounting for 7.9 per cent and 11.4 per cent of the total purchase of computing services, respectively. Similarly, the estimated purchase of cloud services increases over time in terms of both absolute and relative term. Under counterfactual 1, it increases by $25.6 billion USD over the 2006-2014 period to reach $36.1 billion USD in 2014.[19] This accounts for 26.0 per cent of the total purchase made in the country in 2014. Under a more conventional scenario (counterfactual 2), we estimate that the purchase of cloud services reaches $32.1 billion USD in 2014 (an increase of $24.8 billion USD). This accounts for 23.1 per cent of the total purchases made in 2014. This implies that, over the 2006-2014, the purchase of cloud services rose by 16.7 per cent and 20.4 per cent per year under counterfactual 1 and counterfactual 2, respectively.

Table 10: Purchase of cloud computing proxied by the use of data processing, hosting, and related services (BEA Input-Output commodity Code 512), United States, 2006-2014

Difference (Actual - Counterfactual), billions of USD

	Counterfactual 1			Counterfactual 2		
Year	Total	Private	Gov't	Total	Private	Gov't
2006	10.5	5.9	4.6	7.3	4.5	2.7
2007	17.3	13.7	3.7	13.9	12.3	1.7
2008	23.1	16.8	6.4	19.7	15.3	4.4
2009	23.0	9.1	13.9	19.6	7.7	11.9
2010	24.6	9.9	14.7	21.1	8.5	12.6
2011	32.2	18.8	13.4	28.7	17.4	11.4
2012	32.1	19.6	12.5	28.3	18.0	10.3
2013	34.5	28.1	6.4	30.6	26.5	4.1
2014	36.1	31.0	5.2	32.1	29.3	2.8

Ratio of difference to actual purchase, %

	Counterfactual 1			Counterfactual 2		
Year	Total	Private	Gov't	Total	Private	Gov't
2006	11.4	8.8	18.0	7.9	6.8	10.6
2007	16.9	17.8	14.3	13.6	15.9	6.6
2008	21.1	20.7	22.1	17.9	18.9	15.1
2009	21.3	12.6	38.7	18.2	10.7	33.2
2010	21.8	13.2	39.2	18.7	11.3	33.7
2011	26.8	22.4	37.0	23.9	20.7	31.4
2012	25.2	21.7	33.6	22.2	20.0	27.7
2013	26.0	27.8	20.0	23.0	26.2	12.8
2014	26.0	28.9	16.3	23.1	27.3	8.8

Note: Counterfactual 1 is based on the average % GDP observed during 1997-2005. Counterfactual 2 is based on the average % GDP observed during 2000-2005.
Source: Table 8

[19] Over the 2006-2016 period, it increases by $33.6 billion USD under scenario 1. We focus on the 2006-2014 period to be consistent with the Canadian data.

As part of the robustness test, we compare our estimates reported in Table 9 and 10 with the data available from external sources. We expect to see a similar level of revenue or spending associated with cloud services in each country. Most relevant data we found for Canada is from IDC (2016). According to the source, spending on public cloud computing in Canada reached $2,295 million CAD in 2015.[20] Given that this figure only includes public cloud, our estimate of $2,554 million CAD for 2014 under counterfactual 2 appears quite realistic.

For the United States, we refer to the World Semiannual Public Cloud Services Tracker conducted by IDC. According to this source, the worldwide public services revenue reached $45.7 billion USD in 2013 and 68 per cent of the worldwide revenues was attributed to the United States.[21] This implies that the revenue from public cloud services reached $31.1billion USD in 2013. Our estimate for 2013 ranges from $30.6 billion to $34.5 billion USD. For 2014, IDC reported that the worldwide public services revenue reached $56.6 billion USD implying $38.5 billion USD for the United States assuming the share of 68 per cent.[22] For 2014, our estimate suggests that it ranges from $32.1 billion to $36.1 billion USD. Although we tend to underestimate relative to IDC in both years, our estimates are still reasonably similar to the IDC estimates.

The key takeaway from this section is that organizations did respond to a rise of cloud computing by rapidly expanding their spending on cloud services. The annual growth of 20.4 per cent to 25.3 per cent in spending on cloud services indeed reflects their increasing reliance on cloud computing and more importantly, the extent to which the resources are being shifted to current expenditure (*e.g.* purchasing SaaS, PaaS, and IaaS) from expenditure on ICT capital goods.

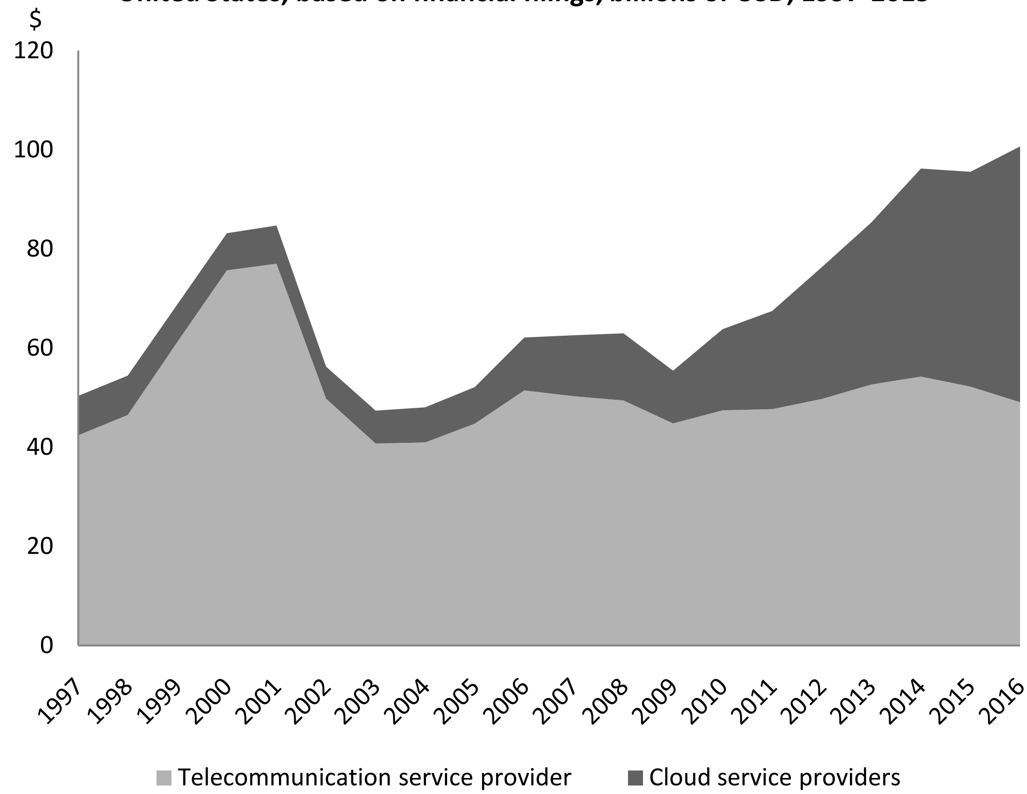
This, in turn, has led to ICT investment by the cloud services industry (both own-account and purchasing final outputs). Although the net effect on the total ICT investment is ambiguous, we argue that the net effect is negative (*i.e.* lower ICT investment) since a cloud service provider's computing resources are pooled to serve many customers based on a multi-tenant model (refer to Section II for detail). A given unit of ICT capital can serve more organizations. As a result, the total demand for ICT capital would be less than the level implied by conventional computing systems (*e.g.* each organization setting up their own ICT infrastructure).

[20] Data for the period prior to 2015 are not available.
[21] See "IDC Expects Public Cloud Sales to Skyrocket through 2018" at http://www.channelfutures.com/idc-expects-public-cloud-sales-skyrocket-through-2018
[22] See "Public Cloud: Trends and Considerations for Business" at https://www.bcx.co.za/download/public-cloud-whitepaper/

IV. Issue Two: Own-account investment in ICT by the IT service sector

We also account for the possibility that cloud service providers assemble ICT equipment on an own-account basis, at least in part. We pay attention to the fact that a large increase in the capital expenditure reflected in financial filings of cloud service providers does not seem to translate into an equivalent increase in the official ICT equipment investment statistics (see Byrne *et al.*, 2017 a, b).

Chart 4: Capital expenditure of selected IT service providers in the United States, based on financial filings, billions of USD, 1997-2015



Note: Included cloud service providers are U.S.-headquartered companies that meet Cisco's definition of "hyperscale" firms (refer to footnote 8 for detail). They include major cloud service providers such as Amazon Web Services, Rackspace, Google, Salesforce, Facebook, Yahoo, ADP, Apple. Included telecommunication providers are AT&T, Verizon, Sprint, T-Mobile U.S., Century Link and related companies. Data are based on company's financial filings.
Source: Byrne *et al.* (2017b)

Based on capital expenditure reflected in financial filings, Byrne *et al.* (2017b) show that major cloud providers have engaged in a large degree of capital investment since 2009 (Chart 4).[23] However, this does not seem to translate into strong investment reflected in the official statistics (Chart 5). Note that not all capital expenditure in Chart 4 occurred within the United States. However, it is likely that most of capital expenditure by cloud service providers would

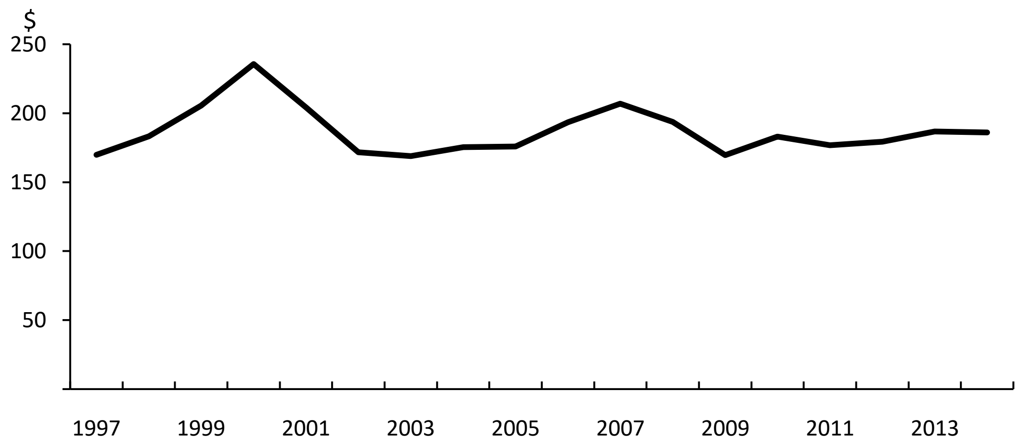
[23] This seems to reflect a massive expenditure on cloud infrastructures to house cloud services and cloud-based resources. For example, for cloud-hosting purpose, large cloud vendors have built multiple data centres of their own.

have occurred within the United States since most of their data centres were built in the country (*e.g.* Google's colocation centre located in New York and AWS's data centre located in Northern Virginia and Ohio.).

Additionally, Byrne *et al.* (2017 a, b) show that IT service sectors in the United States purchased a large amount of computer and electronics components as intermediate goods especially since the mid-2000s suggesting that they have assembled ICT equipment internally. The use of intermediates to build their own ICT equipment is not accounted for by statistics officials as ICT investment and hence leading ICT equipment investment to be underestimated to some extent.

It is true that some non-market production is included in the official statistics such as own-account software production.[24] However, it appears that official statistics do not include ICT equipment produced within establishments for internal use. This is likely to be the case in Canada as well. For example, the questionnaire for the business survey conducted by Statistics Canada does not contain any question regarding own-account capital and infrastructure investment.[25]

Chart 5: Investment in ICT equipment, total economy, United States, billions of USD, 1997-2014



Source: CSLS database for ICT investment. Available at http://www.csls.ca/data/ict.asp

[24] Software produced within establishments for internal use is explicitly included as "own-account software investment" in the United States and "Own-account software design and development services" in Canada.
[25] This information was provided by an official at Consumer and Business Services Surveys Division, Statistics Canada.

A. Trends in the intermediate purchase and output in IT service sectors

In this subsection, we examine the intermediate purchase made by IT services sectors in Canada and the United States to estimate own-account investment in ICT equipment following the method suggested by Byrne *et al.* (2017a, b). For the United States, we simply replicate the findings in Byrne *et al.* (2017a, b) using the I-O tables from BEA. This is to compare the development observed in the United States with that observed in Canada.

Following Byrne *et al.* (2017b), we treat computer and electronic products (IOCC code M334C for Canada and BEA I-O code 334 for the United States) as the most relevant input used by cloud service providers to produce their own ICT equipment infrastructure (*e.g.* servers, storage devices, and network components). For the BEA input-output tables, we do not have enough details publicly available to differentiate the individual components in computer and electronic product. However, we can in the input-output tables published by Statistics Canada. In Canada, the inputs purchased by the sectors related to cloud services are concentrated in the following sub-categories of computer and electronic product (IOCC M334C): telephone apparatus and other communications equipment; computers and computer peripherals and parts; printed and integrated circuits, semiconductors and printed circuit and assemblies; other electronic components.

These are essential parts for building cloud infrastructures such as servers, network switches, and data storage equipment. For example, a large amount of purchases of telecommunications equipment is consistent with the fact that some major cloud service providers started to build their own submarine cables to enhance the interconnectedness of their cloud data centres (*e.g.* Google).

To capture the cloud services sector in a NAICS setting, we focus on a set of sectors called "IT service sectors".[26] This is due to the fact that the primary activity of cloud service providers is covered by more than one sector in NAICS.[27] We believe that the IT service sectors we choose are good representative sectors for the cloud service industry. The IT service sectors have produced over 80 per cent of the total data processing, hosting, and related services on average. For example, in 2014, 84.1 per cent of the total data processing, hosting, and related services (I-O commodity code MPS 518) was produced by the IT service sectors in Canada.[28]Among the IT service sectors, data processing, hosting, and related services (NAICS 51821), telecommunications (NAICS 517), and computer systems and design services (NAICS 5415) accounted for most of the production.[29]

[26] Following Byrne *et al.* (2017a), we define publishing industries, except internet (includes software) (NAICS 511), broadcasting and telecommunications ((NAICS 515 and 517), data processing, hosting and related information services (NAICS 518), other information services(NAICS 519), and computer systems and design services (NAICS 5415) as IT service sectors.

[27]For example, the telecommunications sector is included in our IT service sectors. Note that some large telecommunications firms have shifted a significant part of their business towards providing cloud computing services using their existing infrastructures (*e.g.* AT&T, Telus, T-Mobile, Verizon/Terremark).

[28] The rest of the production of MPS 518 is spread across a number of sectors.

[29] This makes sense since the telecommunications sector now provides cloud services as explained in footnote 27 and the computer systems and design services sector provides services that are highly relevant for cloud computing (*i.e.* for firms that need migration from conventional computing systems to cloud-based systems).

Both in Canada and the United States, the IT service sectors have been purchasing a large amount of computer and electronic products as intermediate. Table 11 and 12 report the intermediate purchase of computer and electronic products by the IT service sector in Canada and the United States based on the input-output tables published by Statistics Canada and the Bureau of Economic Analysis.

Table 11: Intermediate purchase of Computer and electronic products by the IT service sector and its subsectors, millions of CAD, Canada, 1997-2014

Year	Publishing industries , except internet (includes software) (NAICS 511)	Broadcasting and telecommunication (NAICS 515 and 517)	data processing, internet publishing and other information services (NAICS 51821)	Computer systems and design services (NAICS 5415)	Total
1997	41	1,008	18	17	1,084
1998	14	1,046	15	20	1,095
1999	11	972	8	17	1,008
2000	8	1,131	13	19	1,171
2001	10	1,196	13	20	1,239
2002	8	1,287	15	20	1,330
2003	9	1,547	16	23	1,595
2004	11	1,518	19	25	1,573
2005	0	1,665	17	21	1,703
2006	8	1,677	15	20	1,720
2007	9	1,598	14	20	1,,641
2008	9	1,993	15	23	2,040
2009	124	3,065	45	108	3,342
2010	125	3,254	58	149	3,586
2011	162	3,486	73	181	3,903
2012	177	4,073	83	175	4,508
2013	171	4,263	131	234	4,798
2014	208	4,485	124	273	5,089
			Annual Growth Rates, %		
1997-2008	-12.9	6.4	-1.6	2.8	5.9
1997-2006	-16.6	5.8	-2.0	1.8	5.3
2006-2014	50.2	13.1	30.2	38.6	14.5
2006-2008	6.1	9.0	0.00	7.24	8.9
2009-2014	10.9	7.9	22.4	20.4	8.8

Note: Computer and electronic products include: computers and computer peripheral equipment; telephone and other communications equipment; televisions and other audio and video equipment; navigational and guidance instruments; unrecorded magnetic and optical recording media; printed and integrated circuits, semiconductors and printed circuit assemblies; and other electronic components. IT service sector includes: publishing industries, except internet (includes software), broadcasting and telecommunication, data processing, hosting and related information services, other information services, and computer systems and design services.
Source: CANSIM Table 381-0033 and input-output tables published by Statistics Canada (Catalogue 15F0041X).

Before we discuss the data, we present a caveat for the input-output tables for Canada. In Canada, the change in the classification system in 2009 makes the statistics after 2008 not comparable to those prior to 2009. After consulting officials at Statistics Canada on this issue, we conclude that on the industry side, the change is not likely to affect our analysis greatly at the aggregated level (*i.e.* the IT service sector). However, on the product side, the changes in product definitions were significant, making the aggregate statistics (*i.e.* computer and electronic products) potentially incomparable to the previous years. Hence, for Canada, we try to avoid drawing implications without directly comparing the statistics before and after 2009.

In Canada, the total computer and electronic products purchased by the IT service sectors continued to increase over the 1997-2014 period. It reached $5,089 million CAD by 2014.The purchase of computer and electronic products as intermediates grew at 5.3 per cent per year over the 1997-2006 period. However, during the next 8 years (*i.e.* 2006-2014), it grew at an annual rate of 14.5 per cent. Even if we focus separately on the 2006-2008 and the 2009-2014 period due to the 2009 change in the product/industry classification systems, the annualized growth rates are still higher than that annualized over the 1997-2006 period: 8.9 per cent for 2006-2008 period and 8.8 per cent for the 2009-2014 period.

Note that broadcasting and telecommunications are responsible for most of the purchases of the intermediate of computer and electronics components. Unlike the United States, we can differentiate the two sectors in the I-O tables. The data suggest that the intermediate purchase is mainly driven by telecommunications. For example, of the total $4,485 million purchase by broadcasting and telecommunications in 2014, telecommunications accounted for over 97 per cent.

We see a similar trend in the United States. The intermediate purchase of computer and electronics components by the IT service sector increased significantly over the 1997-2016 period. It reached $71.1 billion USD by 2016, up from $10.6 billion USD in 1997. The increase accelerated since 2009. The IT service sectors increased its purchase by $40.0 billion USD over the 2009-2016 period. We do not observe any increase of a comparable degree in the earlier period. In terms of an annual growth rate, the purchase rose at 12.1 per cent per year during the 2006-2016 period. This is significantly higher than the annual growth rate of 8.8 per cent observed during the previous sub-period (*i.e.* 1997-2006).

As shown in Byrne *et al.* (2017b) , this is consistent with the trend we see in Chart 4. Since 2009, cloud service providers started to increase their capital investment significantly. Their capital expenditures increased from $10.6 billion USD in 2009 to $51.6 billion USD by 2016, an increase of $41.0 billion USD (Chart 4). This is very close to the $40.0 billion USD increase in the purchase of computer and electronic components made by the IT service sectors (as categorized based on NAICS) over the same period. Hence, Byrne *et al.* (2017b) suggest that the two data reflect the same underlying phenomenon.

In both countries, telecommunications sectors are largely driving the trend of the total purchase. Yet, as pointed by Byrne *et al.* (2017b), this is not consistent with Chart 4 in which telecommunications providers do not exhibit any strong upward trend. Here, it is important to realize that establishments of cloud services providers could be difficult to distinguish from telecommunications centers as they often engage in activities which, under NAICS, would be categorized as the activity of the telecommunications sector. Note that NAICS used by Statistics Canada and BEA defines industries as sets of establishments which share a common core activity.

Table 12: Intermediate purchase of Computer and electronic products by the IT service sector and its subsectors, millions of USD, United States, 1997-2016

	Publishing industries , except internet (includes software) (NAICS 511)	Broadcasting and telecommunication (NAICS 515 and 517)	data processing, internet publishing and other information services (NAICS 51821)	Computer systems and design services (NAICS 5415)	Total
1997	1,847	6,594	422	1,739	10,602
1998	1,921	6,837	415	2,558	11,731
1999	1,768	9,909	783	3,585	16,045
2000	3,321	12,081	1,323	4,429	21,154
2001	2,962	9,709	1,164	3,477	17,312
2002	2,360	8,922	896	3,602	15,780
2003	2,483	10,427	845	3,292	17,047
2004	2,562	12,392	691	3,059	18,704
2005	2,613	13,529	901	2,869	19,912
2006	3,180	15,694	938	2,825	22,637
2007	2,658	20,447	1,803	2,520	27,428
2008	3,003	18,915	2,393	3,278	27,589
2009	2,703	22,546	2,777	3,019	31,045
2010	2,642	30,230	2,959	4,397	40,228
2011	2,764	38,358	3,750	4,506	49,378
2012	2,425	39,861	5,267	4,739	52,292
2013	2,358	40,545	5,211	4,563	52,677
2014	2,567	41,569	5,595	4,216	53,947
2015	1,856	52,889	5,519	4,207	64,471
2016	1,929	59,290	5,469	4,374	71,062
			Annual Growth Rates, %		
1997-2006	6.2	10.1	9.3	5.5	8.8
2006-2016	-4.9	14.2	19.3	4.5	12.1

Note: Computer and electronic products include: computers and computer peripheral equipment; telephone and other communications equipment; televisions and other audio and video equipment; navigational and guidance instruments; unrecorded magnetic and optical recording media; printed and integrated circuits, semiconductors and printed circuit assemblies; and other electronic components. IT service sector includes: publishing industries, except internet (includes software), broadcasting and telecommunication, data processing, hosting and related information services, other information services, and computer systems and design services.
Source: Input-output tables published by Bureau of Economic Analysis

Byrne *et al.* (2017b) provide some examples: Google's New York headquarters is a major colocation centre (or "carrier hotel"). It is a physical location where data communications media converge and are interconnected. To minimize overhead and optimize communications efficiency, telecommunications firms use this facility to bridge their fiber networks. Another example is that some cloud services firms have begun constructing submarine cables and other portions of the long-haul communications network. For example, Google announced in 2018 that they plan to invest in three new submarine cables of their own in order to increase the amount of bandwidth on their global network interconnecting their cloud data centres.[30] Hence, it appears that the intermediate purchase of computers and electronics by telecommunications based on input-output tables and capital expenditure by the cloud service providers in Chart 4 reflect the same underlying investment activity.

Despite that the IT service sectors have purchased a substantial amount of computer and electronic components, the output data suggest that they have produced essentially zero final computer and electronic products over the 1997-2014. Especially, in both countries, the IT service sectors produced zero output during the period when they substantially increase the purchase of computer and electronic components (*i.e.* 2009-2014).

B. Estimates of own-account investment

Table 13: Estimates of own-account investment, Canada and the United States, 2006-2014

	Canada, millions of CAD		United States, millions of USD	
	(1)	(2)	(1)	(2)
2006	1,720	3,440	22,637	45,274
2007	1,641	3,282	27,428	54,856
2008	2,040	4,080	27,589	55,178
2009	3,342	6,684	31,045	62,090
2010	3,586	7,172	40,228	80,456
2011	3,903	7,805	49,378	98,756
2012	4,508	9,017	52,292	104,584
2013	4,798	9,597	52,677	105,354
2014	5,089	10,178	53,947	107,894

Note: Column (1) is based on the assumption that the value of the own-account production of final computer/electronics is equal to the value of the computer/electronic intermediates used. Column (2) assumes that the value is equal to twice the value of intermediate used.
Source: Author's calculations based on the I-O tables published by Statistics Canada and the Bureau of Economic Analysis.
Source: Table 11 and 12

Data from the input-output tables suggest that cloud service providers are engaging in own-account investment to a great extent. Table 13 reports our estimate of own-account investment for Canada and the United States. The estimates are simply based on the intermediate purchase of computing and electronics components adjusted for the value added from assembling and installing ICT equipment.

[30] See "Three New Submarine Cables to Link Google Cloud Data Centers" and "Will the Submarine Cable Boom Drive More Revenue to Colos?" available at: http://www.datacenterknowledge.com/google-alphabet/three-new-submarine-cables-link-google-cloud-data-centers;http://www.datacenterknowledge.com/archives/2017/02/16/will-new-submarine-cables-boost-data-center-provider-revenue

Expenditures by firms is treated either as intermediate expenditures or as investments. If the sector undertakes own-account investment in ICT equipment, then the costs associated with this activity (*e.g.* costs in purchasing components; costs in assembling and installing ICT equipment) should be capitalized not expensed since these costs create a value that lasts into in the future.

However, it is difficult to precisely estimate the value own-account investment in ICT equipment. Since both Statistics Canada and BEA do not include own-account investment in equipment in the accounts, there is no good template for us to follow. Instead, we refer to their approach in estimating the value of own-account software development.

Statistics Canada assess the value of own-account software development based on an estimation of labour costs for computer programmers and system analysts and other costs (non-salary) of in-house software production. Similarly, BEA estimates own-account investment in software using a "sum of costs" approach. Their estimates are based on production costs such as worker compensation and intermediate expenses. Following this logic and Byrne *et al.* (2017a), we adjust the value of own-account investment by making the following two assumptions: 1. the value of the own-account production of final computer and electronics is equal to the value of the computer and electronic intermediates used; and 2. the value is equal to twice the value of intermediate used.[31]

Based on our conventional estimates (column 1 in Table 13), in Canada, own-account investment in the IT service sectors amounted to $5,089 million CAD in 2014 up from $1,720 million CAD in 2006, an increase of $3,369 million CAD. In the United States, with an increase of $31,310 million USD from 2006 to 2014, own-account investment reached $53,947 million USD in 2014.

Again, the estimates for the United State is consistent with Chart 4 which shows the capital expenditure of major IT service providers (U.S.-headquartered) based on financial filings. From 2006 to 2014, capital expenditure rose by $34,100 million USD (or $31,300 million USD if we consider only the cloud service providers).

We recognize that capital expenditure in Chart 4 also includes investment done outside the United States. However, we argue that a substantial part of the capital expenditure occurred within the United States especially during the period when major cloud service providers first started to build their cloud infrastructures (*e.g.* AWS's data centre located in Northern Virginia and Ohio). Hence, we believe that our estimate and the financial data are reasonably consistent and they represent the same underlying investment activities.

[31] In Byrne *et al.* (2017), they note that the second assumption is still likely to be conservative citing Gartner, Inc's finding that the market value of personal computers is roughly four times the value of electronic inputs.

V. Augmented ICT investment in Canada and the United States

To provide a general idea of the impact of own-account investment on the ICT investment statistics, we augment the official ICT investment measure with the value of own-account ICT investment by the IT service sector. This alternative ICT investment measure would better reflect how ICT investment has responded to the recent rise in the role of cloud computing in the ICT market.

A. Augmented investment in ICT equipment

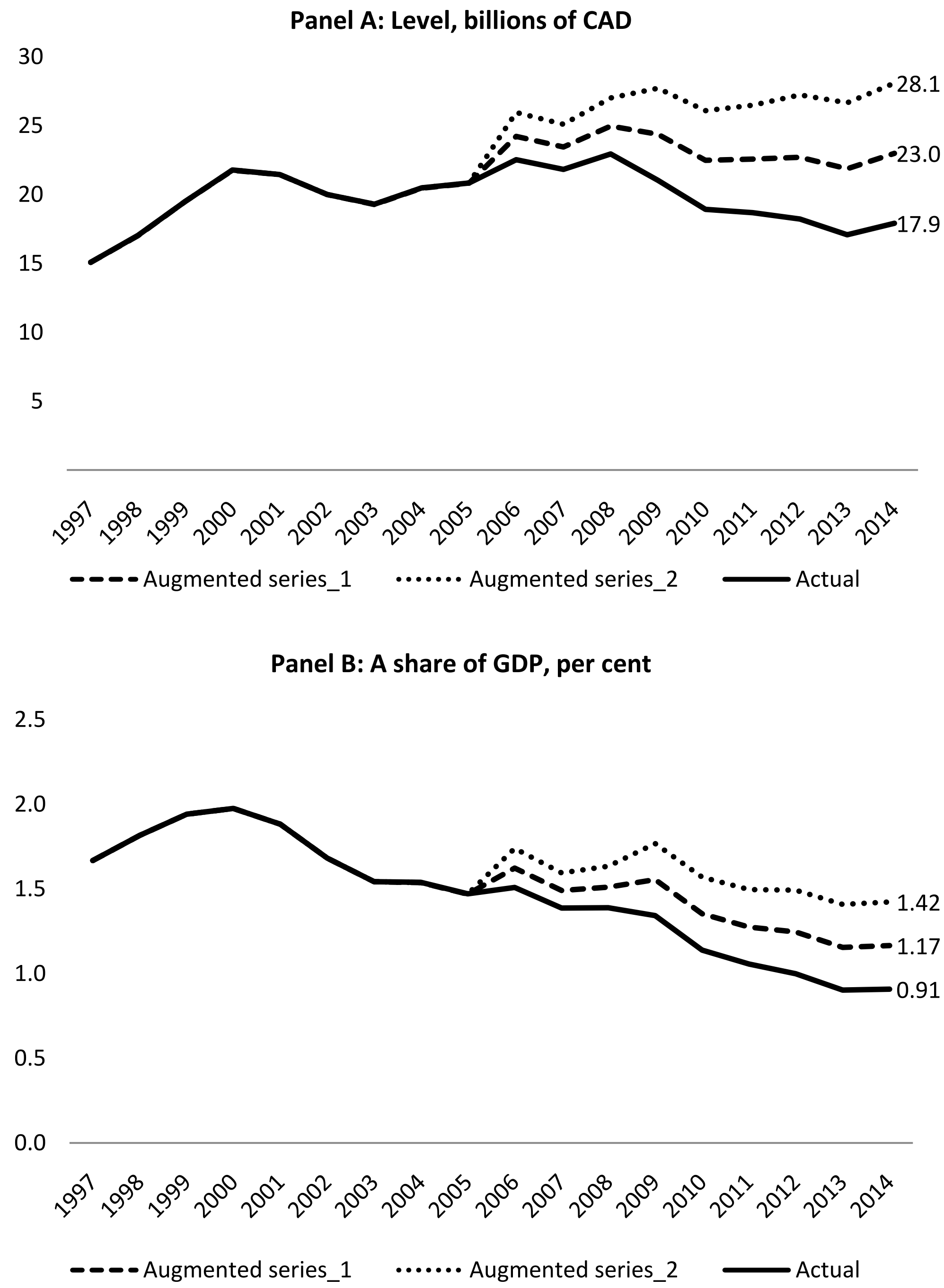
Chart 6 and 7 show the augmented investment in ICT equipment in Canada and the United States using our estimates from Table 13 (see also Appendix Table A1 and A2). Panel A in each chart depicts the level of augmented investment in ICT equipment.

Panel A in Chart 6 shows the level of investment for Canada. Investment in ICT equipment entered a slight downward trajectory following the financial crisis in 2007. Based on the official statistics, investment in ICT equipment did not recover as of 2014. However, adding own-account investment greatly moderate this downward trend or even turns it into a slight upward trend if we adopt a less conservative assumption (augmented series 2).

More importantly, adding own-account investment changes the "weak investment in ICT equipment" story markedly. The augmented investment series implies that a slowdown in the ICT equipment investment after 2000 was of a lesser degree. Appendix Table A1 reports annual growth rates of investment in ICT equipment. Augmenting the statistics changes the annual growth rate for 2006-2014 from -2.82 per cent to as high as 0.99 per cent (adding 3.81 percentage points). To account for the 2009 change in the classification system used in the input-output tables, we also annualize the growth rates separately over the 2006-2008 and 2009-2014 period. A general story holds the same. Adding own-account investment substantially raises the annual growth rates.

In terms of a share in nominal GDP, augmenting the official statistics moderates the downward trend (Panel B in Chart 6). In general, investment in ICT equipment as a share of GDP slowed from 2000. We observe that adding own-account investment on cloud infrastructures from 2006 moderates the downward trend in the share. Instead of falling to 0.91 per cent in 2014 from 1.47 per cent in 2005, our estimate suggests that the share should be in the range of 1.17 per cent to 1.42 per cent in 2014.With the augmented series, the average share ranges from 1.38 per cent to 1.57 per cent during the period 2006-2014 instead of 1.18 per cent (see Appendix Table A2).

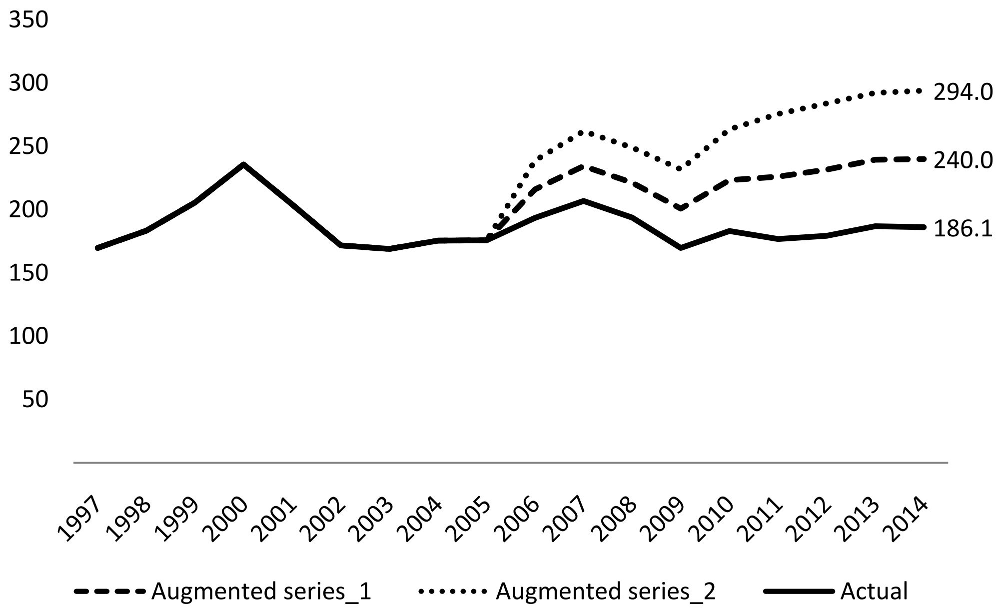
Chart 6: ICT equipment investment augmented by own-account ICT equipment investment by the IT service sector, Canada, billions of CAD, 1997-2014



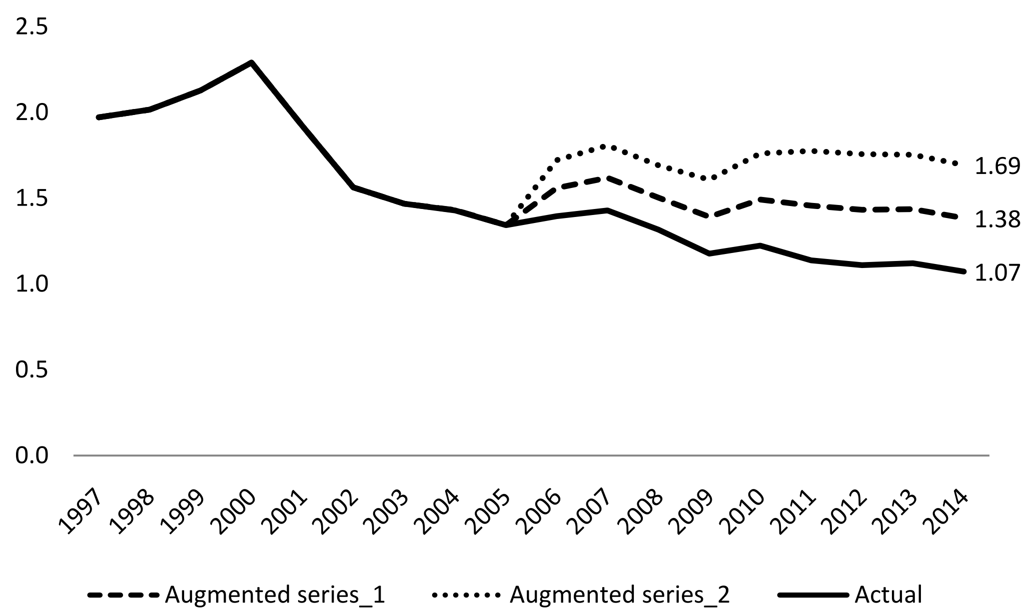
Note: Augmented series_1 and Augmented series_2 correspond to column (1) and (2) in Appendix Table A1, respectively.
Source: Author's calculation based on Table 13 and the CSLS database for ICT investment.

Chart 7: ICT equipment investment augmented by own-account ICT equipment investment by the IT service sector, United States, 1997-2014

Panel A: Level, billions of USD, 1997-2014



Panel B: As a share of GDP, per cent



Note: Augmented series_1 and Augmented series_2 correspond to column (1) and (2) in Appendix Table A1, respectively.
Source: Author's calculation based on Table 13 and the CSLS database for ICT investment.

Panel A in Chart 7 shows the level of ICT equipment investment for the United States. Adding own-account ICT investment by the IT service sector changes the trend quite significantly especially after 2009. The level of investment did not recover significantly after reaching the lowest point during the recession after the financial crisis in 2007. However, our augmented series suggests that the investment in ICT equipment actually recovered and entered a upward trajectory since 2009. In 2014, our estimates show that investment in IT equipment should range from $240.0 to $294.0 billion USD (29.0 per cent to 58.0 per cent higher than the actual statistics).

As in Canada, the United States also experienced notably weak ICT equipment investment especially after 2000. Again, augmenting the series with own-account ICT investment by the IT service sector results in a quite different story. Relative to the official statistics, the annual growth rate implied by the augmented series was much higher. The investment in ICT equipment fell during the period 2006-2014 with an annual rate of -0.48 per cent. Augmenting the series changes the negative rate to a positive rate during this period: -0.48 per cent to 2.64 per cent. This is additional 3.12 percentage points (see Appendix Table A1).

A stronger ICT investment is also found in terms of a share of GDP. The share continued to decline from 2006 based on the official data. Adding own-account ICT investment by the IT service sector again changes this trend. The augmented series suggests that investment in ICT equipment as a share of GDP in 2014 should be in the range of 1.38 per cent to 1.69 per cent instead of 1.07 per cent (Panel B in Chart 7). This is the result of an increasing share from 2005: the share stood at 1.34 per cent. Moreover, we find that during the 2006-2014 period, the average share is higher than that suggested by the official statistics. During this period, our estimates imply that the average share should range from 1.47 per cent to 1.73 per cent instead of 1.22 per cent as suggested by the official statistics.

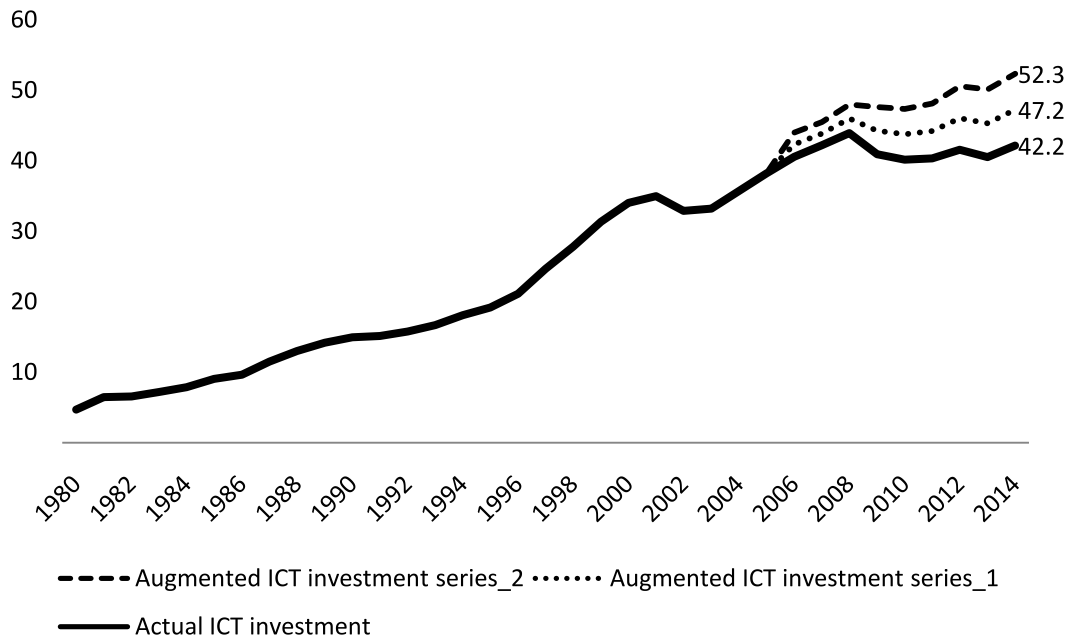
B. Augmented ICT investment

How would total ICT investment have evolved in the two countries if own-account investment by the IT service sectors are taken into account? In Section I, we show that ICT investment in both countries grew at a much slower rate and its share in GDP fell since the early 2000s (see Chart 1 and Table 1). Chart 12 and 13 depict official ICT investment series along with two sets of augmented series. Appendix Table A3 and A4 presents the data points in those two charts from 2006 along with annualized growth rates and average shares in GDP.

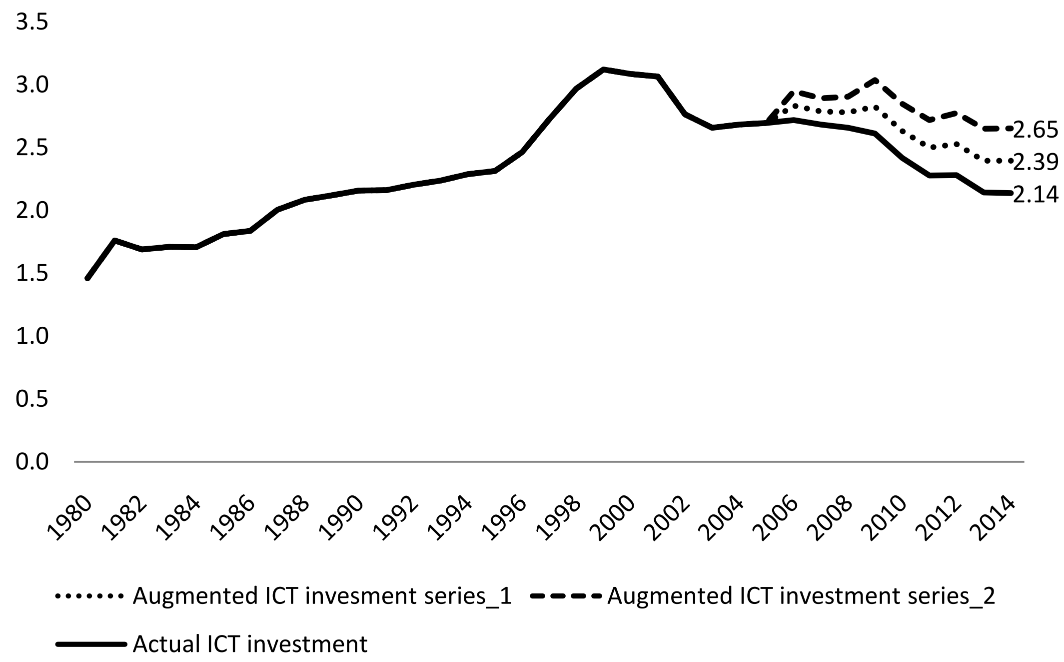
Panel A in Chart 8 shows the level of ICT investment in Canada. ICT investment reached the highest in 2008 after recovering from a brief slump following the burst of the dot com bubble. From 2008, ICT investment started to fall and it did not recover fully as of 2014. Adding our estimates to the ICT investment changes the trend markedly. While the official series of ICT investment fell by $1.7 billion CAD from 2008 to 2014, augmented series 2 suggests that it actually increased by $4.3 billion CAD.

Chart 8: ICT investment (augmented and actual), Canada, billions of CAD, 1997-2014

Panel A: Level, billions of CAD



Panel B: As a share of GDP, per cent



Note: Augmented series_1 and Augmented series_2 correspond to column (1) and (2) in Appendix Table A1, respectively.
Source: Author's calculation based on Appendix Table A1 and the CSLS database for ICT investment. Available at http://www.csls.ca/data/ict.asp

A more important result is that augmenting the official series implies stronger ICT investment in terms of both an annual growth rate and a share of GDP. First, when we augment the official series with the own-account investment, the annual growth rate during the 2006-2014 period is raised by as much as 1.71 percentage points: 0.48 per cent vs. 2.19 per cent (see Appendix Table A3).[32] This is a substantial addition.

Panel B shows ICT investment as a share of GDP. As we discussed, the share of ICT investment has been on a downward trajectory since the early 2000s. Although this is still true with our augmented series, the downward trend is much attenuated. Note that the downward trend becomes more pronounced after 2006 according to the official statistics. With the augmented series 2, the share stabilizes after 2006 instead of falling. The share reaches 2.65 per cent, down from 2.70 per cent in 2005. This contrasts to the official statistics which shows a 0.66 percentage-points-decrease from 2005 to reach 2.14 per cent in 2014.[33]

Chart 9 shows the official and augmented ICT investment series for the United States. Again, adding our estimates to the official series changes the picture quite considerably. After the trough in 2009, official ICT investment recovered to $539.8 billion USD by 2014 from $460.4 billion USD in 2009, an increase of$79.4 billion USD. The estimates based on augmented series 2 suggest that ICT investment at the 2009 trough is $522.5 billion USD instead of $460.4 billion USD. With an increase of $125.2 billion USD from 2009, the level of ICT investment reaches as high as $647.7 billion USD in 2014.

More important to us is that the annual growth rates tend to be higher with the augmented series during the period 2006-2014 (see Appendix Table A3). The own-account investment in cloud infrastructures boosts the annual growth rate by as much as 1.12 percentage points during this period: 3.34 per cent instead of 2.22 per cent.

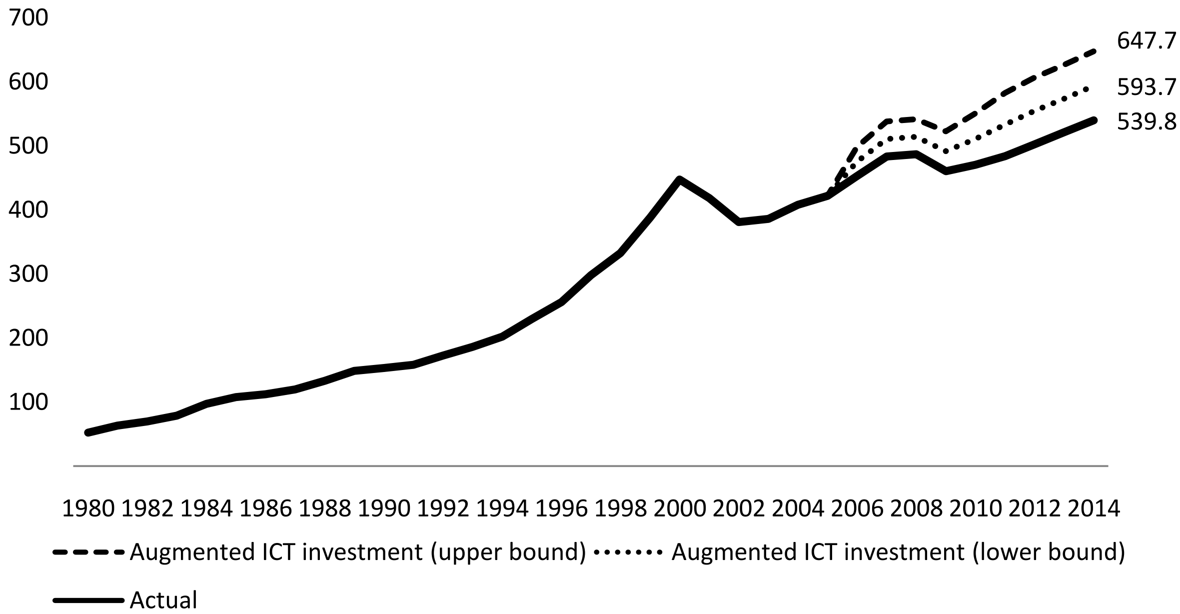
We also observe stronger ICT investment in terms of a share of GDP (Panel B in Chart 9). Unlike Canada, the United States did not enter a clear downward trajectory in the share from 2006. However, ICT investment still remained weak as the share stayed below the level observed in the early 2000s. Augmenting the series changes this trend significantly. Our augmented series suggests that the share of ICT investment should have reached 3.42 per cent to 3.73per cent by 2014 instead of 3.11 per cent. This implies that ICT investment (as a share of GDP) had a meaningful recovery since the slump in the early 2000s. Our estimates indicate that the average share during the 2006-2014 period should be in the range of 3.45 per cent to 3.70 per cent. This compares to the average share of 3.19 per cent suggested by the official statistics during this period (see Appendix Table A3).

[32] The same pattern holds true if the growth rate annualized separately over the 2009-2014 period (accounting for the change in the classification system in the input-output tables in 2009). The annual growth rate was as weak as 0.60 per cent during this period. However, the augmented series implies that the growth rate could have been as high as 1.91 per cent per year.

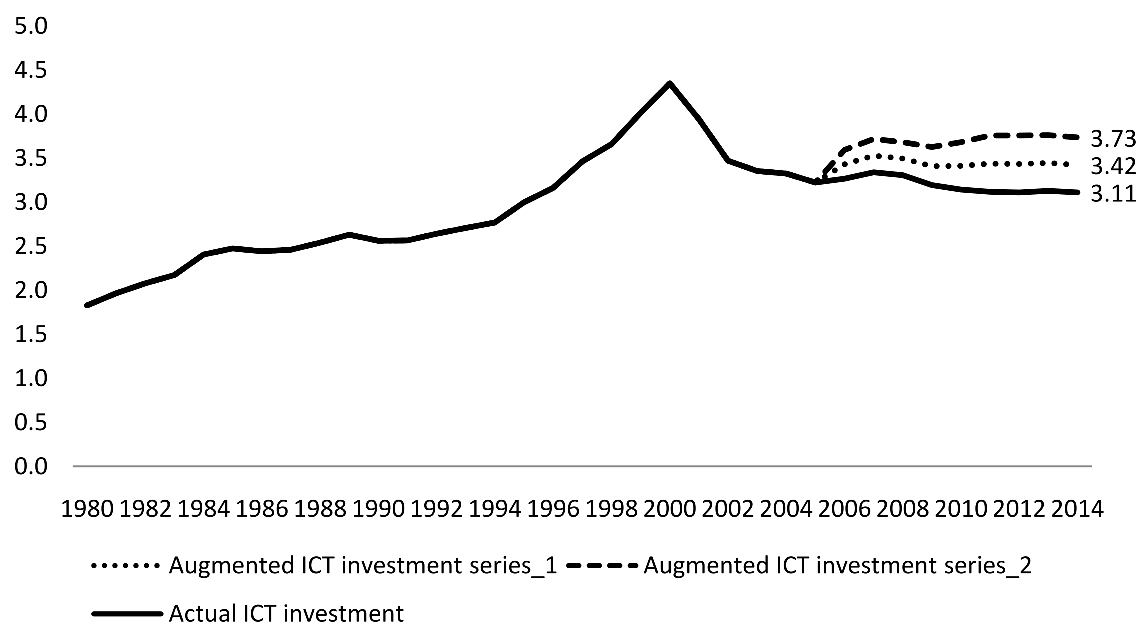
[33] The average share stands at 2.82 per cent during the 2000-2005 period but it fall to 2.44 per cent during the 2006-2014 period (see Appendix Table A3). With the augmented series, the average share ranges from 2.63 per cent to 2.82 per cent during the 2006-2014 period.

Chart 9: ICT investment (augmented and actual), billions of USD, United States,1980-2014

Panel A: Level, billions of USD



Panel B: As a shre of GDP, per cent



Note: Augmented series_1 and Augmented series_2 correspond to column (1) and (2) in Appendix Table A1, respectively.
Source: Author's calculation based on Appendix Table A1 and the CSLS database for ICT investment.

Although these augmented series are exploratory and should be assessed cautiously, the key takeaway is that ICT investment in both Canada and the United States appears to have responded significantly to the recent rise of cloud computing in their economies. For both countries, a significant part of the "weak ICT investment story" discussed in Section I (with Chart 1 and Table 1) can be attributed to own-account equipment investment by cloud service providers.

We conclude this section by suggesting that there are other important measures potentially being underestimated in the official statistics. For example, adding own-account investment by the IT sector to ICT equipment would lead to a higher capital stock and labour productivity growth. For example, Byrne and Corrado (2017) show that the contribution of ICT technologies to labour productivity is substantial (1.4 percentage points per year). More importantly, they find that about 25 per cent of the total ICT contribution is attributed to the diffusion of ICT technology through purchases of cloud and related ICT services.

GDP is also a good example in this case. Appendix Table A4 present actual and augmented nominal GDP for Canada and the United States. Accounting for own-account investment by the IT service sectors would raise the 2014 GDP in Canada by 0.52 percent and add 0.04 percentage point to the annual growth rate of GDP during the 2006-2014 period (based on the augmented series 2). For the United States, it would raise the 2014 GDP by 0.62 per cent and add 0.04 percentage point to the growth rate from 2006 to 2014 (see Appendix Table A4).

VI. Conclusion

This report explores the potential role of cloud computing in explaining the weak ICT investment in Canada and the United States. Specifically, we hypothesize that the weak ICT investment might be due in part to the shift of expense from capital to services. Cloud computing allows organizations to access computing resources without having tangible and intangible infrastructures on premises. Second, major cloud services providers now undertake own-account investment (*e.g.* assembling servers and building cloud infrastructures internally). Such investment is omitted from official statistics. For example, a discussion with some officials at Statistics Canada revealed that own-account investment in ICT equipment is not included in the official ICT investment series in Canada.

We summarize our main findings as follows. Using the input-output tables, we estimate that the purchase of cloud services in Canada reached $2,554 million CAD in 2014, up from $420 million CAD in 2006, resulting in an annual growth rate of 25.3 per cent. In the United States, our estimate suggests that the purchase of cloud services reached $32.1 billion USD, up from $7.3 billion USD in 2006. This implies an annual growth rate of 20.4 per cent. These estimates are consistent with the IDC estimates of spending on cloud services in Canada and the United States. In both countries, our results suggest that a substantial amount of resources has been reallocated from purchasing ICT capital goods to purchasing cloud services.

Second, we estimate own-account ICT equipment investment in the "IT service sector" which presumably cover core activities of cloud service providers. Based on our conventional estimates, own-account ICT investment by the IT service sector in Canada reached $5.1 billion CAD by 2014. In the United States, it reached $53.9 billion USD in 2014, up from $22.6 billion USD in

2006. This is an increase of $31.3 billion USD over the 8-year period. This is consistent with the trend in capital expenditure (based on financial filings) worldwide by major cloud service providers headquartered in the United States. From 2006 to 2014, their capital expenditure increased by $31.3 billion USD. We argue that a substantial share of this increase occurred within the United States as major cloud service providers had built their main data centres and cloud infrastructures across the country.

Adding our estimates of own-account ICT investment by the IT service sector to official ICT investment statistics changes ICT investment performance markedly. With the augmented ICT investment statistics, in Canada, ICT investment as a share of GDP stabilizes after 2006 instead of falling. In terms of an average annual growth rate, ICT investment growth still slows down after 2006 but the degree is lessened. Adding own-account investment results in an additional 1.71 percentage-points annual growth in the nominal ICT investment during the 2006-2014 period. In the United States, adding own-account investment results in a slight upward trend in the ICT investment as a share of GDP. Also, it leads to an annual growth rate of 3.34 per cent during the 2006-2014 period, 1.12 percentage points higher than the actual annual rate.

This report is exploratory in nature in addressing the two important facets of the changing ICT spending pattern driven by a rise of cloud computing. In this report, we propose a line of research on the impact of cloud computing on ICT investment activities. We hope our research leads to further debate on cloud computing and better data collection on the cloud services sector. This would contribute not only to better measurement of ICT investment but also to a better understanding of the changing ICT spending pattern in an increasingly digitalized economy.

We conclude our report by suggesting some future directions for data collection on the cloud services sector as well as future research agendas. First, questions regarding own-account investment in ICT equipment should be included in the survey for the computing services industry done by Statistics Canada and the Bureau of Economic Analysis. This would resolve the measurement issue we discuss in section IV.

Second, we suggest that the breakdown of sales in computing services sectors (as in Table 6) includes a separate category for cloud services as cloud services are increasingly important intermediate inputs purchased by the total economy in Canada and the United States. Better estimates of the purchase of cloud services would help researchers shed more light on the changing ICT spending pattern and its impact on the overall economy.

Finally, it would be useful to compile official data that indicate how much of cloud services are provided by the firms based in the United States to organizations in Canada. This is related to a future research direction we present in the following.

Research on the market structure of cloud computing in North America would be important. In this report, we estimate the purchase of cloud services made by organizations in Canada. Note that it is likely that Canadian organizations purchase a substantial amount of cloud services from the U.S.-based firms with Canadian operations. There is enough anecdotal evidence to motivate research on how much of the total cloud services purchased in Canada is from the firms in the United States. For example, there are U.S.-based cloud service providers that have substantial

Canadian operations but without main data centres located within Canada.[34] The IDC report in 2015 indicates that these two firms hold over 50 per cent of the total Canadian market share.[35] If this is indeed true, then the changing ICT spending pattern in Canada is largely supported or facilitated by the cloud service providers in the United States. Moreover, most of capital expenditure by major cloud service providers would have occurred within the United States rather than in Canada.

Due to the lack of official data on the cloud services sector, we currently do not have a full picture on the cloud computing market in Canada. The cloud computing market in Canada is most likely to be in the form of oligopoly with a few major cloud service providers dominating the market. Examples are Google, Microsoft Azure, and Amazon Web Services. Although much smaller in size, we do have cloud service providers based in Canada such as Bell, Cogeco, Rogers, Telus, and CenturyLink. These are the cloud service providers serving Canadian organizations with their data centres located within Canada.[36]

There are a number of signs that these Canadian cloud service providers are expanding their cloud businesses within Canada. For example, Telus recently announced construction of a new $65 million data centre in Rimouski, Quebec to provide cloud services. In 2018, Bell also announced that they are building a new data centre ($100 million) in Ottawa.[37] However, with current official data, we cannot assess the role of these Canadian firms in providing cloud services to customers in Canada. A relevant statistic to construct would be a concentration ratio of major cloud service providers (U.S- and Canada-based, respectively) in the cloud computing market in Canada. This would have implications for the market share of the U.S.-based cloud service providers in the Canadian cloud computing market.

Another line of research can be on the relationship between a higher utilization rate of ICT resources via cloud computing and the change in demand for ICT capital goods. Throughout the report, we emphasize that cloud computing leads to a higher utilization rate of ICT infrastructures within cloud service providers. However, we do not attempt to explicitly quantify the effect of such efficiency gain on ICT investment in the report.

Before cloud computing, it was common for a firm to install servers and data storage devices separately for each department. Such a deployment system of IT equipment inherently has a lower capital utilization rate than cloud computing due to difficulty in server integration. The difficulty is stemmed from differences between servers' busy and idle periods and differences in

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[34] Amazon Web Service (AWS) does have a data centre in Canada. However, most of the infrastructure owned by AWS and other major cloud service providers is located within the United States.

[35] See "Top 10 Canadian cloud providers revealed: IDC Canada" at https://www.computerdealernews.com/news/top-10-canadian-cloud-providers-revealed-idc-canada/39892

[36] For example, Cogeco has data centres in Barrie, Toronto, and Montreal; CenturyLink in Vancouver, Toronto, and Montreal; Rogers in Vancouver, Edmonton, Calgary, Oakville, Toronto, London, Hamilton, Ottawa, and Halifax.

[37] See "TELUS to build $65 million Intelligent Internet Data Centres in Rimouski, Quebec" at https://www.newswire.ca/news-releases/telus-to-build-65-million-intelligent-internet-data-centre-in-rimouski-quebec-508253731.html. For Bell, see "New Bell Data Centre to Offer National Capital Region enhanced security, availability, and energy efficiency" at https://www.newswire.ca/news-releases/new-bell-data-centre-to-offer-national-capital-region-enhanced-security-availability-and-energy-efficiency-507481001.html

system life cycles. Cloud computing solves these problems since a cloud service provider's computing resources are pooled to serve many organizations based on a multi-tenant model. A given unit of ICT capital resource of cloud service providers can support more ICT operations than the same unit of ICT resource of individual organizations without cloud computing.

Hence, we hypothesize that the net effect of cloud computing on the demand for ICT capital goods is likely to be negative due in large part to the efficiency gain within cloud service providers. This efficiency gain could more than offset the increase in demand for ICT capital goods by cloud service providers as they meet the demand for their services. We believe that this phenomenon could explain a large part of the "weak ICT investment" story in Canada and the United States.

References

Bain and Company (2017), The Changing Faces of the Cloud, available at http://www.bain.de/Images/BAIN_BRIEF_The_Changing_Faces_of_the_Cloud.pdf

Byrne D., and Corrado, C. (2017), ICT Services and Their Prices: What Do They Tell Us About Productivity and Technology?, International Productivity Monitor,No.33, pp.150-181

Byrne D., Corrado, C., and Sichel, D. (2017a), The Rise of Cloud Computing: Minding Your P's and Q's, Paper presented at the NBER/CRIW conference, Measuring and Accounting for Innovation in the 21st century, held in Washington, D.C., March 10-11, 2017.

Byrne D., Corrado, C., and Sichel, D. (2017b), Own-Account IT Equipment Investment, Feds Note, October 4t, 2017 https://www.federalreserve.gov/econres/notes/feds-notes/own-account-it-equipment-investment-20171004.htm

Canadian Channel Chiefs Council (2017), The Dynamics of the Canadian IT Market, Cloud Adoption Rates, and the Status of the Channel https://www.channelchiefs.ca/wp-content/uploads/2017/05/C4-Ryerson-IDC-Joint-Research-Study-v2.pdf

International Data Corporation (2015), IDC FutureScape: Worldwide Cloud 2016 Predictions - Mastering the Raw Material of Digital Transformation, IDC report #259840

International Data Corporation (2016), How the Microsoft Ecosystem and Cloud Computing Will Create 110,000 New Jobs in Canada from 2015 to 2020, IDC report #CA41566716

International Trade Administration (2016), 2016 Top Markets Report Cloud Computing, https://www.trade.gov/topmarkets/pdf/Cloud_Computing_Top_Markets_Report.pdf

Kuwazu, K. (2015), Increased Adoption of Cloud Services and Its Impact on the ICT Market, *Nomura Research Institute*, No. 205

KPMG (2017), Journey to the Cloud, https://assets.kpmg.com/content/dam/kpmg/xx/pdf/2017/02/the-creative-cios-agenda-journey-to-cloud.PDF

Mell Peter and Timothy Grance (2011), The NIST definition of Cloud Computing, NIST Special Publication 800-145

Thomas, Jasmin (2015), An Analysis of the Canada-U.S. ICT Investment Gap: An Update to 2013, CSLS research report 2015-01.

Thomas, Jasmin (2016), New Evidence on the Canada-U.S. ICT Investment Gap, 1976-2014, CSLS research report 2016-17

VII. Appendix: Additional Tables and Charts

A. Tables

Table A1: Augmented investment in ICT equipment, Canada and the United States, 2006-2016

	Canada(billions of CAD)			United States(billions of USD)		
	Actual	Augmented (billions of CAD)		Actual	Augmented (billions of USD)	
		(1)	(2)		(1)	(2)
2006	22.5	24.2	26.0	193.4	216.0	238.6
2007	21.8	23.5	25.1	206.9	234.3	261.7
2008	22.9	25.0	27.0	193.8	221.4	249.0
2009	21.0	24.4	27.7	169.6	200.7	231.7
2010	18.9	22.5	26.1	183.0	223.2	263.4
2011	18.7	22.6	26.5	176.7	226.1	275.4
2012	18.2	22.7	27.2	179.2	231.5	283.8
2013	17.1	21.9	26.7	186.8	239.4	292.1
2014	17.9	23.0	28.1	186.1	240.0	294.0
			Annual Growth Rate (%)			
2006-2014	-2.82	-0.65	0.99	-0.48	1.33	2.64
2006-2008	0.94	1.53	2.03	-	-	-
2009-2014	-3.16	-1.16	0.26	-	-	-

Note: Column (1) is based on the assumption that the value of the own-account production of final computer/electronics is equal to the value of the computer/electronic intermediates used. Column (2) assumes that the value is equal to twice the value of intermediate used. To account for the 2009 change in the classification system used in the input-output tables, we annualize the growth rate separately over the 2006-2008 and 2009-2014 period for Canada.

Source: Author's calculations based on the I-O tables published by Statistics Canada and the Bureau of Economic Analysis.

Table A2: Augmented investment in ICT equipment as a share of nominal GDP, Canada and the United States, per cent, 2006-2016

	Canada			United States		
	Actual	Augmented series		Actual	Augmented series	
		(1)	(2)		(1)	(2)
2006	1.51	1.62	1.74	1.40	1.56	1.72
2007	1.39	1.49	1.60	1.43	1.62	1.81
2008	1.39	1.51	1.63	1.32	1.50	1.69
2009	1.34	1.56	1.77	1.18	1.39	1.61
2010	1.14	1.35	1.57	1.22	1.49	1.76
2011	1.06	1.28	1.50	1.14	1.46	1.77
2012	1.00	1.25	1.49	1.11	1.43	1.76
2013	0.90	1.16	1.41	1.12	1.44	1.75
2014	0.91	1.17	1.42	1.07	1.38	1.69
Average Share						
2006-2014	1.18	1.38	1.57	1.22	1.47	1.73

Note: Column (1) is based on the assumption that the value of the own-account production of final computer/electronics is equal to the value of the computer/electronic intermediates used. Column (2) assumes that the value is equal to twice the value of intermediate used.

Source: Author's calculations based on the I-O tables published by Statistics Canada and the Bureau of Economic Analysis.

Table A3: Augmented ICT investment, Canada and the United States, 2006-2016

	Canada (billions of CAD)			United States (billions of USD)		
	Actual	Augmented (billions of CAD)		Actual	Augmented (billions of USD)	
-		(1)	(2)		(1)	(2)
2006	40.6	42.3	44.0	452.7	475.3	498.0
2007	42.2	43.8	45.5	483.4	510.8	538.3
2008	43.9	46.0	48.0	486.7	514.3	541.9
2009	40.9	44.3	47.6	460.4	491.5	522.5
2010	40.2	43.8	47.3	470.5	510.7	550.9
2011	40.3	44.2	48.1	484.0	533.4	582.8
2012	41.5	46.0	50.5	502.2	554.5	606.8
2013	40.5	45.3	50.1	521.2	573.9	626.6
2014	42.2	47.2	52.3	539.8	593.7	647.7
			Annual Growth Rate (%)			
2006-2014	0.48	1.40	2.19	2.22	2.82	3.34
2006-2008	4.06	4.26	7.82	-	-	-
2009-2014	0.60	1.31	1.91	-	-	-

Note: Augmented series_1 and Augmented series_2 correspond to column (1) and (2) in Appendix Table A1, respectively. To account for the 2009 change in the classification system used in the input-output tables, we annualize the growth rate separately over the 2006-2008 and 2009-2014 period for Canada.

Source: Author's calculation using the data in Appendix Table A1 and the CSLS database for ICT investment. Available at http://www.csls.ca/data/ict.asp

Table A4: Augmented ICT investment as a share of nominal GDP, Canada and the United States,per cent, 2006-2016

	Canada			United States		
	Actual	Augmented series		Actual	Augmented series	
		(1)	(2)		(1)	(2)
2006	2.72	2.83	2.95	3.27	3.43	3.59
2007	2.68	2.79	2.89	3.34	3.53	3.72
2008	2.66	2.78	2.90	3.31	3.49	3.68
2009	2.61	2.82	3.04	3.19	3.41	3.62
2010	2.42	2.63	2.85	3.14	3.41	3.68
2011	2.28	2.50	2.72	3.12	3.44	3.76
2012	2.28	2.53	2.77	3.11	3.43	3.76
2013	2.14	2.39	2.65	3.13	3.44	3.76
2014	2.14	2.39	2.65	3.11	3.42	3.73
Average Share						
2006-2014	2.44	2.63	2.82	3.19	3.45	3.70

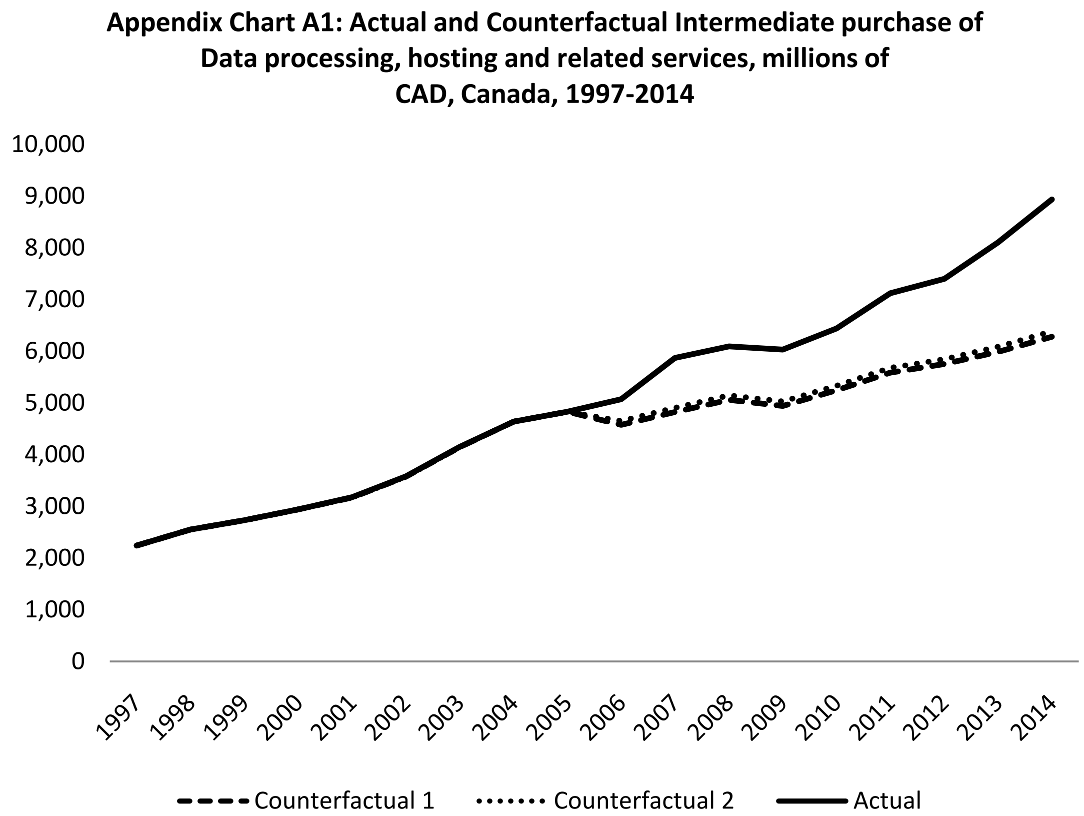
Note: Column (1) is based on the assumption that the value of the own-account production of final computer/electronics is equal to the value of the computer/electronic intermediates used. Column (2) assumes that the value is equal to twice the value of intermediate used.
Source: Author's calculations based on the I-O tables published by Statistics Canada and the Bureau of Economic Analysis.

Table A5: Gross Domestic Product, Actual and Augmented, current prices, 2006-2014

	Actual	Augmented 1	Augmented 2
	Canada, millions of CAD		
2006	1,492.2	1,495.6	1,493.9
2007	1,573.5	1,576.8	1,575.2
2008	1,652.9	1,657.0	1,655.0
2009	1,567.4	1,574.0	1,570.7
2010	1,662.1	1,669.3	1,,665.7
2011	1,769.9	1,777.7	1,773.8
2012	1,822.8	1,831.8	1,827.3
2013	1,892.2	1,901.8	1,897.0
2014	1,973.0	1,983.2	1,978.1
	Growth rates, %		
2006-2014	3.55	3.59	3.57
2006-2008	5.25	5.29	5.28
2009-2014	4.71	4.72	4.71
	United States, millions of USD		
	Actual	Augmented 1	Augmented 2
2006	13,855.9	13,901.2	13,878.5
2007	14,477.6	14,532.5	14,505.1
2008	14,718.6	14,773.8	14,746.2
2009	14,418.7	14,480.8	14,449.8
2010	14,964.4	15,044.8	15,004.6
2011	15,517.9	15,616.7	15,567.3
2012	16,155.3	16,259.8	16,207.5
2013	16,663.2	16,768.5	16,715.8
2014	17,348.1	17,456.0	17,402.0
	Annualized growth rates, %		
2006-2014	2.85	2.89	2.87
2006-2008	3.07	3.09	3.08
2009-2014	3.77	3.81	3.79

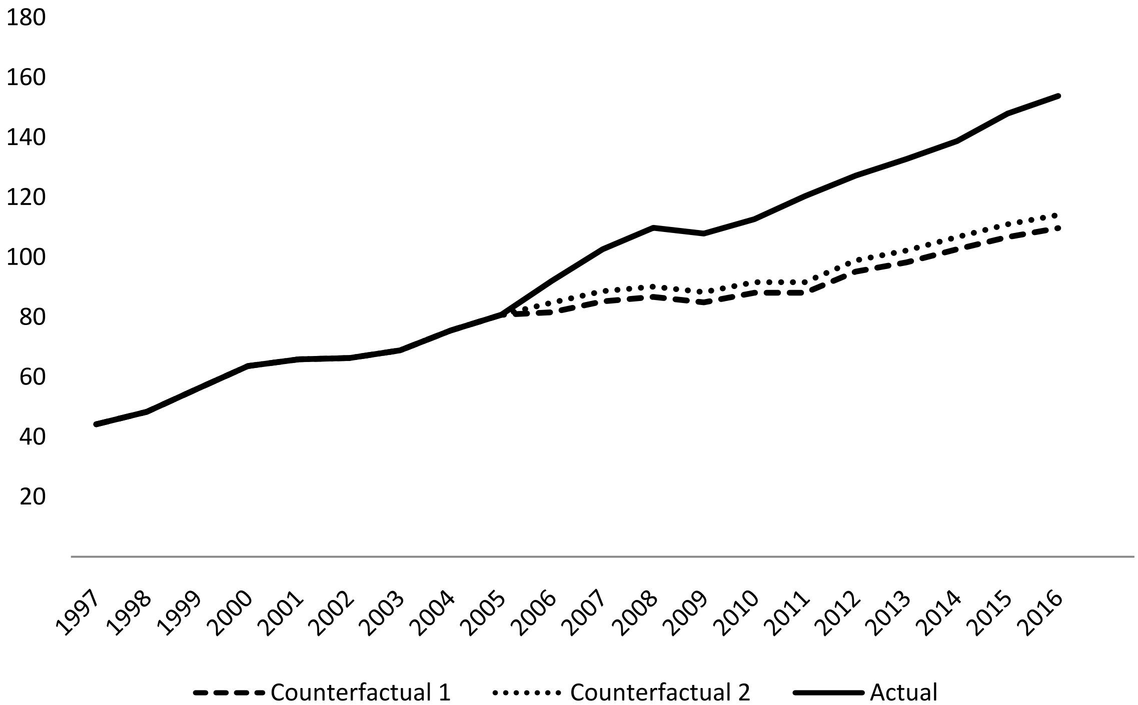
Note: Augmented 1 and 2 are based on column (1) and (2) respectively in Table A1.
Source: Author's calculation based on Table A1 and the CSLS database for ICT investment. Available at http://www.csls.ca/data/ict.asp

B. Charts



Source: Author's calculations based on CANSIM Table 381-0033 and input-output tables published by Statistics Canada (Catalogue 15F0041X).

Appendix Chart A2: Actual and Counterfactual Intermediate purchase of Data processing, hosting and related services, billions of USD, the United States, 1997-2016



Source: Author's calculations based on input-output tables from the Bureau of Economic Analysis.