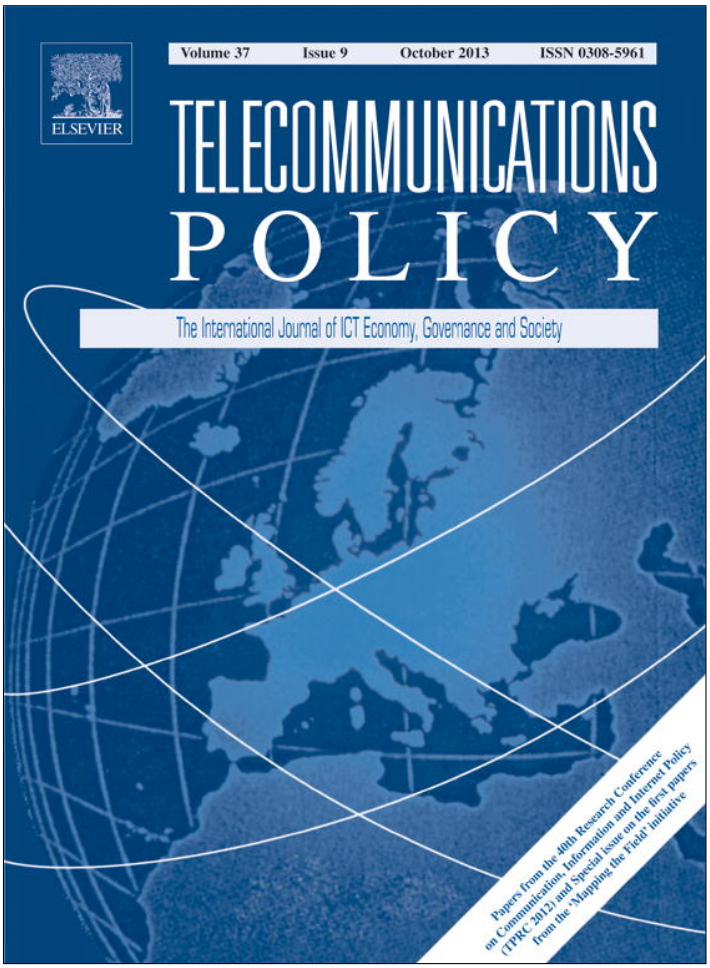

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Multilevel governance and broadband infrastructure development: Evidence from Canada ☆

Reza Rajabiun *, Catherine A. Middleton

Ted Rogers School of Information Technology Management, Ryerson University, 350 Victoria Street, Toronto, Canada ON M5B 2K3

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ABSTRACT

This paper investigates the contributions of digital infrastructure policies of provincial governments in Canada to the development of broadband networks. Using measurements of broadband network speeds between 2007 and 2011, the paper analyzes potential causes for observed differences in network performance growth across the provinces, including geography, Internet use intensity, platform competition, and provincial broadband policies. The analysis suggests provincial policies that employed public sector procurement power to open access to essential facilities and channeled public investments in Internet backbone infrastructure were associated with the emergence of relatively high quality broadband networks. However, a weak essential facilities regime and regulatory barriers to entry at the national level limit the scope for decentralized policy solutions.

1. Introduction

Diffusion of high-speed broadband networks has a significant positive impact on business productivity and aggregate levels of economic growth (Czernich, Falck, Kretschmer, & Woessmann, 2011; Qiang, Rossotto, & Kimura, 2009). A large and growing body of cross-country studies explores the impact of competition regulations and industrial policies on broadband market outcomes such as penetration, prices and speeds (Bauer, 2010; Berkman Center for Internet and Society, 2010; Belloc, Nicita, & Rossi, 2012; Cambini & Jiang, 2009). However, there has been relatively little attention devoted to the role lower levels of government can play in stimulating competition and investment in the provision of high-speed network infrastructure. Understanding this role and evaluating the effectiveness of different local policy strategies are important particularly in large and diverse federations such as the United States, European Union, China, Russia, and Canada. When policies by the central government do not produce satisfactory results, decentralized solutions can offer additional options for addressing infrastructure access and quality problems.

This paper investigates the relationship between digital infrastructure policies of provincial governments in Canada and the development of broadband networks. The next section provides an overview of the evolution of broadband Internet connectivity in Canada. Section 3 reviews the literature, noting theoretical reasons for policy decentralization in digital infrastructure development and studies of the impact of policy on broadband. Section 4 characterizes the development of Internet connectivity in Canada using measurements of network speeds between 2007 and 2011 and evaluates potential sources of provincial variation, including geography, demand intensity, and public policy. Section 5 draws inferences from the Canadian experience for the design of broadband policy in multilevel systems of governance.

* Corresponding author. Tel.: +1 416 833 4864.
E-mail addresses: reza.rajabiun@gmail.com (R. Rajabiun), catherine.middleton@ryerson.ca (C.A. Middleton).

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2. Broadband in Canada

In the late 1990s and early 2000s Canadian providers expanded Internet access to a relatively larger proportion of the population more rapidly than most other advanced economies (OECD, 2012a; van Gorp & Middleton, 2010). Some observers of comparative telecommunication policy attributed this success to Canada's federal telecommunication policy regime and used Canada as an example for other countries to emulate (Atkinson, Correa, & Hedlund, 2008; Bouras, Giannaka, & Tsiatsos, 2009; Frieden, 2005; Wu, 2004).

Although Canada ranked either first or second in terms of broadband take-up during the early stages of broadband rollouts, since the mid 2000s many advanced countries have achieved higher adoption rates and Canada is now ranked thirteenth in the OECD in terms of fixed broadband subscriptions (OECD, 2012c). Despite the growing lag in aggregate adoption rates, Canada's telecommunications regulator (the Canadian Radio–television and Telecommunications Commission, (CRTC, 2012)) reports that fixed broadband connectivity is available at 100% of urban and 83% of rural premises in Canada.

Canadian federal and provincial governments define broadband as a connection that provides a minimum download speed of 1.5 Mbps. This level of performance may be sufficient for first generation Internet applications such as email and simple web browsing, but is not enough for deploying more advanced applications (e.g. multimedia, cloud computing, IPTV; CRTC, 2011a; Ezel, Atkinson, Castro, & Ou, 2009). According to user generated measures of broadband network performance from Ookla Net Metrics/Speedtest (2012), average download speeds that Canadian end users achieve are between 2 to 3 times lower than those in a number of countries in Europe and Asia. Furthermore, although physical access to DSL and cable broadband is widespread across the country, rollout of next generation fiber-to-the-premises (FTTP) technologies has been limited (Waverman, Dasgupta, & Rajala, 2011). As of mid-2012, fewer than 2% of fixed broadband connections in Canada were fiber, compared to 7% in the US and well below the OECD average of 14% (OECD, 2012b).

The relatively low network speeds and slow deployment of next generation networks in Canada are particularly puzzling given that aggregate capital expenditures on telecommunications infrastructure and the level of platform competition in Canada have been higher than average for other high income countries (ITU, 2010; OECD, 2011a). Relatively high prices in the Canadian broadband market (OECD, 2011b) attract more investment, but the capital expenditures on telecommunications infrastructure have not yet led to the emergence of an internationally competitive broadband system in terms of connectivity speeds or the diffusion of advanced fiber networks.

National policymakers have expressed concerns about Canada's comparative decline as a broadband leader. The 2006 Telecommunications Policy Review Panel (TPRP) highlighted difficulties for dominant operators to meet growing demand for Internet connectivity and outlined a number of specific reforms to the federal regulatory framework to address the problem. These included moving away from implicit subsidies for operators, relaxing regulatory barriers to international investment, and strengthening Canada's essential facilities regime. While it is not clear if these reforms would have worked, substantive elements of institutional reforms proposed by TPRP have not been implemented.

The 2010 Consultation Paper on Canada's Digital Economy Strategy also expressed concern about the pace of progress in network infrastructure development and drew attention to international broadband speed measurements to point out that "Canada ranks in the middle of the pack" (Government of Canada, 2010, p. 16). However, the federal government has not yet offered substantive solutions that could reverse broadband trends of concern to end users and the business community. Indeed, despite initiating a consultation on a digital strategy for Canada in 2010, no such strategy has been delivered by the federal government. The CRTC has set a target for broadband speeds (5 Mbps download, 1 Mbps upload to be available to all Canadians by 2015), but notes that over 80% of households already have access at these speeds and offers no specific strategy to encourage network expansion or increased speeds (CRTC, 2011b).

In contrast, the European Commission has set a target of making 30 Mbps service available to all households in the EU by 2020, with 100 Mbps service adopted by more than 50% of households by that time (European Commission, 2010). The US National Broadband Plan calls for 100 million US homes to have access to 100 Mbps download and 50 Mbps upload speeds by 2020 (Federal Communications Commission, 2010). Australia has not only set aggressive targets, it is building a national broadband network capable of delivering speeds of up to 1 Gbps to 93% of premises (Department of Broadband Communications and the Digital Economy, 2013). The government of Brazil is studying options to develop a national fiber network to provide backhaul and last mile connectivity in all its regions (Telegeography, 2013). While assessments like the Connectivity Scorecard (Waverman, Dasgupta, & Rajala, 2011) suggest that Canada is doing reasonably well when broadband speeds are compared to Western European countries, without a strategy or ambitious targets to improve speeds over time, and with take-up of FTTP technologies lagging other economies, it is not clear that Canada will maintain broadband parity with other developed nations in the next decade.

Given the lack of action at the national level, provincial and municipal governments are designing and implementing local policies aimed at improving digital infrastructure access and performance. Provincial policies in Canada have been diverse, and include direct investments in Internet backbone infrastructure, targeted private sector subsidies, public ownership, and the use of strategic procurement policy as a tool for shaping market behavior of network operators. Consequently, the Canadian experience provides a unique basis for exploring different approaches to broadband development policy and investigating the role sub-national governments can play in promoting digital infrastructure development within regulatory constraints posed by higher levels of government.

3. Literature review

Deploying broadband networks is fundamentally a local enterprise, requiring estimates of demand, upgrades to legacy copper telephone and cable networks and switching facilities, and/or installing advanced fiber-to-premises/hybrid fiber-wireless networks. Given the importance of local knowledge about demand and supply conditions, it might appear optimal to allocate infrastructure development policy authority to the lowest possible level of government. On the other hand, there are significant economies of scale in the administration of broadband networks. This creates pressure for corporate consolidation and oligopolistic structures that transcend local, state, and often national jurisdictional boundaries.

Centralization of policy authority can reduce duplication and delay relative to a decentralized system of governance. It also provides a basis for spreading the fixed costs of regulation across a larger population of taxpayers (Montolio & Trillas, 2013; Mulligan & Shleifer, 2005). Decentralization can be costly because it creates some risk that local authorities erect regulatory barriers to entry in an attempt to extract part of the super-normal profits that arise in oligopolistic industries such as telecommunications (Brennan, 2001). Furthermore, jurisdictional competition creates the potential for a "race to the bottom" (e.g. in terms of subsidies and tax breaks), and policy decentralization may increase the costs of regulatory compliance for network providers that operate in multiple jurisdictions (Hoffinger, 2003; Lehr & Kiessling, 1999; Sun & Pelkmans, 1995). Consequently, the optimal allocation of telecommunications policy authority is theoretically ambiguous.

In the United States the tension between the local nature of network infrastructure deployment and scale economies in its management provides the basis for a long history of debates about the authority of state and federal governments in telecommunications policy (Lyons, 2010; Nuechterlein & Weiser, 2005; Santorelli, 2010). More recently, the impetus for policy coordination and centralization of broadband network access regulations in the European Union has also highlighted this tension (Brito, Pereira, & Vareda, 2011; Simpson, 2011).

3.1. Theory: federalism and broadband policy

Economic theories of federalism offer a number of arguments relevant for the allocation of policy authority in broadband network development. As highlighted by Tiebout (1956), jurisdictional competition can yield optimally differentiated local policies that are more efficient at matching local preferences for the supply of public goods than a centralized system of governance. Policy decentralization can also increase political participation and transparency, enhancing institutional capacity to search for policies that are more reflective of local needs and conditions (Inman & Rubinfeld, 1997). Furthermore, federalist governance structures increase the number of veto points in political systems and can make it more difficult for governments to expropriate specific capital investments ex post (Weingast, 1995). Consequently, multilevel governance may increase private sector incentives to invest in infrastructure projects that require irreversible capital expenditures relative to unitary policy hierarchies. In the context of broadband network development, this version of the separation of power argument is particularly salient in the regulation of access to essential facilities. Adopting regulations that require network operators to share their assets with third parties can lead to expropriation of specific capital investments by platform operators, reducing their ex ante incentives to invest in network capacity upgrades and adoption of new technologies (Kotakorpi, 2006; Laffont & Tirole, 2000). Centralization of access regulation constrains the ability of local governments to engage in this kind of expropriation. On the other hand, a weak essential facilities regime at the central level increases the risk of investment to potential entrants that require access to existing facilities (i.e. last mile copper and cable links, local switching hubs, towers, existing fixtures from other utilities such as electricity infrastructure).

Emphasizing the ambiguity in the allocation of telecommunications policy authority, Montolio and Trillas (2013) provide a theoretical framework where different levels of government specialize in the type of tasks in which they have a comparative advantage. They point out that central government entities might be better at accounting for interjurisdictional externalities associated with broadband network development (e.g. when individuals in one jurisdiction benefit from a good network in another, interoperability, regulatory compliance costs, etc.). However, having a high quality broadband network also reduces the costs of delivering other public goods such as healthcare and education. Lower levels of governments that are responsible for the delivery of social and business infrastructure might have stronger incentives to account for the benefits of digital infrastructure than central government authorities. In such a case, it might be optimal to allocate the authority to regulate access to essential facilities at the central level and decentralize industrial policies aimed at promoting investment into network infrastructure to lower levels of government.

3.2. Evidence: public policy, market competition and broadband development

There is a large literature going back before the Internet age on the impact of essential facilities access regulations on private incentives for the provision of telecommunications infrastructure. Cambini and Jiang (2009) provide a thorough review of quantitative cross-country studies focusing on broadband connectivity and find that the results are mixed. There is some evidence that OECD countries with higher levels of inter-platform competition (as opposed to service-based competition) have experienced relatively faster broadband penetration growth (Bouckaert, van Dijk, & Verboven, 2010). However, others have found that the intensity of service-based competition in the market for the provision of Internet access services has been particularly important for increasing broadband penetration in the early stages of the diffusion of high-speed connectivity and in maturing broadband markets where penetration rates start to approach a maximum (Belloc

et al., 2012). Montolio and Trillas (2013) analyzed the links between measures of administrative and political centralization, market structure, and unbundling regulation on broadband penetration rates in OECD countries. They found market concentration levels and indicators of policy centralization have a significant negative impact on broadband penetration rates. Although the effect of industrial subsidies was not clear, stronger unbundling regulations were associated with higher broadband penetration levels.

Bauer (2010) discusses various reasons for difficulties in the empirical identification of optimal competition policy design in telecommunications, including the static nature of the methodology of earlier studies and difficulties in controlling for contextual variables such as market structure and demand intensity. Despite ambiguities in cross-country studies, contradictions in their results highlight an empirical puzzle with particular relevance for the analysis of the Canadian broadband experience that follows in the next sections. More restrictive obligations on platform operators to provide third parties access to essential network facilities appear to be negatively associated with the level of investments by dominant operators (Grajek and Roller, 2012). However, there is also a growing body of research that suggests open access policies lead to the development of higher quality broadband networks (Berkman Center for Internet and Society, 2010; Choi, 2011). Relatively restrained essential facilities regimes might be conducive to platform competition and capital expenditures on legacy networks, but facilities-based competition and higher levels of investment do not always translate into relatively higher penetration growth and pace of network quality improvements.

In addition to cross-country assessments of public policy and broadband connectivity, there are a large number of case studies that focus on the impact of municipal broadband projects, a review of which is beyond the scope of this paper. However, in an analysis of approximately 60 municipal broadband projects in Western Europe, Troulos and Maglaris (2011) found that the success of local initiatives is highly dependent on the national regulatory and policy environment.

Very few studies have tried to analyze the impact of state and provincial policies on network infrastructure development. Wallsten (2005) studied the association between various U.S. state level broadband promotion policies and broadband penetration growth. He found state mandates guaranteeing access to rights-of-way and higher levels of competition from non-incumbent operators had a positive impact on broadband deployment. Universal service mechanisms with implicit subsidies for incumbent telephone companies were negatively associated with broadband deployment. The impact of other policy instruments that aimed to promote the supply of broadband such as grants, loans, and tax breaks appears to have been insignificant.

4. Policy objectives and instruments in Canada

Due to their distinctive responsibilities, objectives of different levels of government can diverge, often substantially. While the telecommunications sector in Canada is regulated federally, provinces are primarily responsible for delivering public goods such as healthcare, education, and business infrastructure. This constitutional arrangement suggests that relative to the national government, the provinces might have stronger incentives to care about digital infrastructure that enables them to increase business productivity, attract mobile capital and reduce the costs of delivering other public goods (an exploration of the impact of broadband in improving delivery of public goods is beyond the scope of the paper, but is discussed in detail in reports by the Broadband Commission for Digital Development (2011) and the Broadband Commission Working Group on Education (2013)). As a result perceptions of local policymakers about optimal network quality and access levels might differ from that of national regulators. The range of instruments available to national and provincial governments also differs.

4.1. Federal policy framework

Canadian constitutional federalism provides wide ranging powers to the provinces to regulate social and economic activity, but does not explicitly assign jurisdiction over telecommunications to the federal or provincial governments. Nevertheless, the constitution provides the federal government with the power to regulate undertakings that are interprovincial or international in character (Ryan, 2011), and in a series of cases from the late 1980s and early 1990s, the Supreme Court of Canada extended federal jurisdiction over telecommunications operators that provided services within one province (*Alberta Government Telephones v CRTC* ([1989] 2S.C.R. 225) and *Téléphone Guèvremont Inc v Québec* ([1994] 1S.C.R. 878)).

The Telecommunications Act (1993) consolidated older laws governing the industry and codified the objectives of Canadian telecommunications policy. Section 7 of the Act outlines these aims and emphasizes “that telecommunications performs an essential role in the maintenance of Canada's identity and sovereignty”. The statute includes a number of potentially conflicting objectives, including the “orderly” deployment of telecommunications systems that “safeguard, enrich and strengthen the social and economic fabric of Canada and its regions” (S.7.a), enhance “efficiency and competitiveness” of the industry (S.7.c), and promote the “ownership and control of Canadian carriers by Canadians” (S.7.d). It also stipulated “increased reliance on market forces for the provision of telecommunications services” (S.7.f). Further to Section 7.f of the Act, in 2006 the federal government directed the CRTC to "(i) rely on market forces to the maximum extent feasible as the means of achieving the telecommunications policy objectives, and (ii) when relying on regulation, use measures that are efficient and proportionate to their purpose and that interfere with the operation of competitive market forces to the minimum extent necessary to meet the policy objectives” (Governor in Council, 2006).

Unlike most other advanced economies, Canada continues to limit non-Canadian entities from taking a controlling stake in network operators. Noticing early signs of Canada's comparative decline as a broadband leader, the 2006 Telecommunication Policy Review Panel recommended relaxing these barriers in order to promote competition and investment in the provision of Internet access services (TPRP, 2006). Although some wireless licenses have been granted to non-Canadian entities subsequent to the TPRP recommendations, and restrictions on foreign control of smaller telecommunications facilities operators were recently relaxed (as part of Bill C-38, i.e. the 2012 budget implementation bill), regulatory barriers that limit competition in the market for corporate control of Canadian network providers remain in place. In addition to potentially adverse effects on management efficiency of dominant operators, barriers to foreign control reduce the prospects for the emergence of new competition by making it more difficult for potential entrants to raise external capital. Although it is too early to assess the impact of the limited relaxation of the foreign ownership/control rules on promoting entry and investment in broadband, in the longer term operators and sub-national governments might be able to exploit this opening in order to stimulate the development of next generation networks.

In terms of domestic competition regulation, a 1994 Review of Regulatory Framework (Telecom Decision CRTC 94-19) determined that increasing competition in the local telecommunications market was in the public interest. Canada was one of the first countries to publish a detailed regulatory framework for unbundling local loops and pricing co-location and interconnection to specific facilities considered essential for creating a competitive market for the provision of network connectivity (Telecom Decision CRTC 97-8). However, a combination of high access prices, sunset provisions in the essential facilities regulations, and hesitation in the enforcement of the rules limited the initial effectiveness of the unbundling mandate (Berkman Center for Internet and Society, 2010).

As it became more apparent that the regulatory framework was not sufficient to promote competition, the CRTC extended the unbundling mandate indefinitely in 2001 and in 2008 reduced regulated prices—from 25% to 15% markup on incremental costs (Telecom Decision CRTC 2008-17). Nevertheless, these adjustments were insufficient and the level of service-based competition in the provision of Internet access on first generation broadband technologies remained limited (van Gorp & Middleton, 2010). Further changes to the wholesale access regime were mandated in 2011 (Telecom Decisions CRTC 2011-703 and 2011-704, with clarification on pricing issued in 2013 (Telecom Decision CRTC 2013-70). The impact of these changes will not be seen immediately but if effective, the incumbents' market share of residential subscribers should drop from the 93% held in 2011 (CRTC, 2012).

The CRTC's failure to create an effective essential facilities regime has generated various proposals to remove its power to interpret interconnection rules in favor of a more independent adjudication venue (Iacobucci & Trebilcock, 2007; TPRP, 2006). To date, proposals for removing regulatory barriers to entry and increasing the credibility of the essential facilities regime have been ignored.

Canada's relatively restrained essential facilities regime helps explain why capital expenditures on telecommunications infrastructure have been higher than average for high income countries and why there is a relatively high degree of competition between cable and DSL operators (ITU, 2010; OECD, 2011a). The Canadian experience is interesting in the context of broader international trends noted in the last section because higher levels of aggregate capital expenditures have not necessarily translated into relatively higher network quality in terms of speeds, or strong incentives for the diffusion of next generation FTTP networks. Limited incentives to deploy new broadband technologies (e.g. FTTP) are also puzzling because the regulator has clearly signaled that it will exercise forbearance and has classified fiber access and transport facilities as non-essential (Telecom Decision CRTC 2008-17). This observation from Canada is particularly relevant for other countries debating the design of access regimes for next generation broadband networks (Choi, 2011; OECD, 2013).

While incentives for substantive regulatory reforms appear limited, over the past decade the federal government has funded various programs intended to expand broadband access in rural and remote areas. These have included targeted grants to provinces through the Canadian Strategic Infrastructure Fund (CSIF), Broadband for Rural and Northern Development (BRAND), and the National Satellite Initiative (NSI), as well as subsidies for private providers administered directly by the federal government (Connecting Rural Canadians at $225 mil.). A set of decisions by the CRTC in 2010 allowed incumbent telephone network operators to keep nearly half a billion dollars of overcharges from urban customers in order to expand rural broadband connectivity (Telecom Decisions CRTC 2010-637, 638, and 639). As concerns about broadband *availability* have been resolved, questions about improving the *performance* of Canada's broadband infrastructure and creating incentives for deploying more advanced technologies required for the widespread utilization of advanced ICT applications have become increasingly important for both federal and provincial policymakers.

4.2. Provincial policy strategies

As noted, because provinces are responsible for the delivery of various public services, they have strong incentives to encourage the development of quality broadband networks. In Canada however, national policies constrain the set of policy strategies available to lower levels of government. For example, barriers to foreign participation in the market reduce the range of potential suppliers in public procurement processes. This increases the expected costs of using public funds to promote broadband infrastructure development and therefore reduces incentives to do so. A weak interconnection regime also makes it more costly to use non-incumbent entities to promote supply and can lead to inefficient duplication because firms that control essential facilities would have limited incentives to provide non-incumbents with access to existing

essential facilities. However, the provinces do not have the authority to change the federal interconnection regime or regulatory barriers to entry.

Digital infrastructure policies of Canadian provinces have been diverse and multifaceted. Most provinces have some form of supply subsidy program for expanding rural connectivity. Some provinces only focus policy initiatives on addressing market failures in rural and remote communities. These include Ontario and Quebec, which hold most of the country's population. Saskatchewan retains public ownership of the copper platform operator, Alberta has made direct investments in backbone infrastructure of the network (i.e. Alberta SuperNet), and British Columbia (BC) has employed public procurement as a strategic tool for stimulating broadband network development. Given growing concerns about digital infrastructure quality, a number of provinces including Quebec and Saskatchewan have recently announced significant public investment commitments to broadband (Bianchini, 2012). In addition to the continuation of the traditional model of public ownership and formal corporate control, provincial policy strategies in Canada can be divided into three general categories:

4.2.1. Subsidies for rural and remote areas

The potential for under-investment in rural areas has led to the adoption of a wide range of programs at the federal and provincial levels that subsidize private investment in delivering Internet connectivity to rural, remote and First Nations communities. This class of initiatives has typically focused on projects financing part of the capital expenditures required for delivering broadband to end users. Different approaches have been adopted by the provinces to design rural broadband subsidies, allocating program budgets, and structuring public–private partnerships. For example, the Connecting Citizens Grant Program in British Columbia involved three rounds of funding totaling around $8 mil. for about 150 relatively small projects intended to enhance connectivity at the community level. The program capped per project funding at $50,000 and most projects received this fixed amount. Incumbent operators were excluded from the process. In contrast, the Rural Connections Broadband Program in Ontario invested around $32 mil. in 54 larger projects. The median project subsidy for the Ontario program was about $500,000 and private participants were expected to contribute two thirds of necessary capital expenditures for increasing connectivity speeds to 1.5 Mbps. In Nova Scotia the province and federal government provided subsidies to private sector providers to develop fixed wireless infrastructure to cover the entire province with 1.5 Mbps service.

From 2009 to 2012, the federal Connecting Rural Canadians program targeted rural areas. Average project subsidies of about $2 mil. per project covered up to half of project costs. A number of multilevel initiatives involving federal, provincial, and municipal governments have also helped expand access in rural and remote areas (e.g. Eastern Ontario Regional Network (EORN), Infrastructure Canada grants). The effectiveness of different approaches to rural program design has not been studied and represents an interesting avenue for future research.

4.2.2. Direct public investment in the Internet backbone

Unlike other large federations such as Australia, Brazil and Russia, the Government of Canada has shown little interest in investing directly in the commercial Internet backbone. At the provincial level, Alberta has adopted this policy option. Although the exact level of public sector commitment is not clear, publicly available data suggests that since 2001 the Alberta government has invested at least $193 mil. in the Alberta SuperNet (Service Alberta, 2012). The SuperNet was designed to achieve two objectives: First, the network served as the basis for improving the delivery of government services by connecting around 4200 schools, hospitals, libraries, and municipal offices in both urban and rural areas with high-capacity fiber links. Second, the SuperNet was also intended to encourage rural economic development through broadband connectivity (Service Alberta, 2012).

The contract to build the network was granted to Bell Canada, which is the incumbent telecom operator in Eastern Canada, but not in Alberta. Bell also received a contract to operate the network in 27 urban areas, while the contract to operate the network in 402 smaller communities and act as a wholesaler was granted to a smaller non-incumbent entity, Axia NetMedia. The government committed to purchasing infrastructure services it requires from these operators, but the amount of the procurement guarantee has not been disclosed. Axia is not to provide retail services and offers wholesale access to the backbone from 400 points of presence (POP) based on a uniform pricing model. Retail ISPs must provide the necessary infrastructure for connecting from the SuperNet POP to customer premises, which means they must either install their own fixed or wireless connections, or interconnect through existing facilities that are controlled by the local incumbent TELUS. Given weaknesses in Canada's essential facilities regime, exclusion of the incumbent from the project has created a particularly big challenge for third party ISPs and limited the capacity of the SuperNet as a platform for bringing high-speed connectivity to rural Alberta (see e.g. Telecom Decision CRTC 2009-326).

4.2.3. Strategic procurement policy

As large buyers of digital infrastructure and information technology services, local governments can promote network development by aggregating demand and shaping the behavior of operators through contractual arrangements (Gillett, Lehr, & Osorio, 2004). In contrast to the public ownership model and the utilization of non-incumbent operators for building and running the SuperNet, the British Columbia government has tried to promote high-speed Internet connectivity through a series of contracts between the provincial government and the incumbent TELUS that link public sector information technology purchases to commitments by TELUS to upgrade its network and provide essential facilities access to third party ISPs (Connecting Communities Agreement (CCA) and Connecting British Columbia Agreement (CBCA)). Under these

arrangements TELUS agreed to maintain Internet gateway points at around 120 communities throughout the province, provide affordable access to these gateways to third party providers, and increase network speeds up to ten-fold in particular areas (Network BC, 2012). This approach has limited the need to invest public funds directly in infrastructure development and reduced the potential for duplication. In addition to leveraging its procurement power to improve core infrastructure components and mitigating concerns about essential facilities access associated with the federal regulatory regime, the British Columbia government provided seed money to local private and non-profit service providers to extend last mile connectivity in rural and remote areas. However, this approach has also meant locking in public procurement decisions about long distance telephone calls, conferencing, voice, data, and other services required by core ministries, health authorities, and other public corporations to one firm for extended periods.

5. Broadband network development in Canadian provinces

The evolution of broadband networks in Canada offers a unique window into international debates about the interaction between technological change, public policy, and private sector decision processes that shape Internet connectivity. As noted, Canada has extensive broadband *coverage*, but with broadband currently defined as a 1.5 Mbps service policy concerns have turned to the *performance* of Canada's digital infrastructure. For example, the consultation paper on Canada's Digital Economy Strategy references two sources of speed measurements (Akamai Technologies and Speedtest/Ookla Net Metrics) to highlight that the pace of progress in network development may not be sufficient to meet growing demand for network resources (Government of Canada, 2010). Since substantive changes to Canada's national policy strategy have not been forthcoming, decentralized solutions by the provinces represent a viable option for mitigating concerns by end users and the business community about the quality of Internet connectivity in the country. There has been little research that benchmarks and analyzes provincial variation in broadband infrastructure performance.

5.1. Broadband speed measurements

Various approaches to measuring network performance have been developed. At the end user level, there are many utilities that allow even novice users to monitor speed and other characteristics of their Internet connections. However, aggregating individual tests into indicators of performance reflective of larger systems is difficult and controversial (Bauer, Clark, & Lehr, 2010). As a result, there is little consensus about which approach to measuring speed captures reality in absolute terms. Furthermore, the market for Internet connectivity is highly differentiated in terms of both supply and demand. As a result significant caution must be used in interpreting aggregate indicators of broadband network outcomes (e.g. availability, price, speed, etc.). Two basic approaches to collecting speed measurements have been developed and used in policy discussions:

- **Active tests** require an action by end users to initiate a process that assesses the quality of Internet connectivity (e.g. download/upload speeds, latency, jitter, etc). Examples of this approach include indicators from Speedtest/Ookla Net Metrics and the Network Diagnostic Test (NDT)/M-Lab infrastructure. Raw data from both test-beds is publicly available.
- **Passive tests** compile performance measurements without an explicit decision by end users to initiate a test, usually during the content or application delivery process. Measurements from Akamai, Google/You-Tube, and Netflix represent examples of this approach. Akamai routinely publishes measurements from the logs of its servers for a number of countries, as well as U.S. states. These indicators are often quoted in comparative assessments of Canada's broadband network quality with other countries (e.g. CRTC, 2012; Government of Canada, 2010).

Different tests reflect distinctive windows into the complex world of Internet connectivity (see Bauer et al. (2010) for a detailed discussion of these differences). Consequently, their results can differ substantially both in absolute and relative terms (e.g. across ISPs, jurisdictions). As Fig. 1 illustrates, average speed estimates of Canadian provinces from Ookla Net Metrics/Speedtest tend to be around two times higher than those measured by Akamai. There are also some inconsistencies in the relative rankings of particular provinces across the two tests.

Averaging measurements from active and passive tests provides a more comprehensive picture of the quality of service end users experience. Fig. 2 documents the percentage deviation of the provinces from the provincial mean based on the

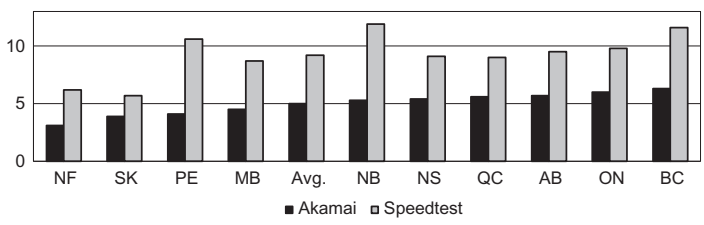

Fig. 1. Passive vs. active measurements (average speed in Mbps; Q1-2011).

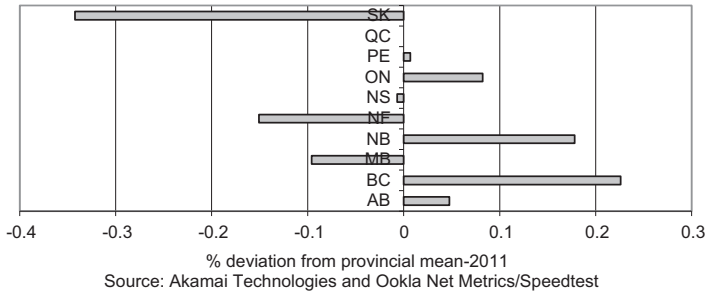

Fig. 2. Provincial differences in broadband speeds.

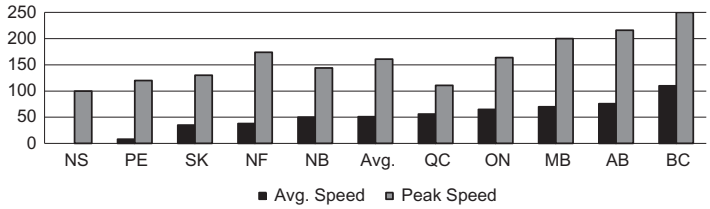

Fig. 3. Cumulative growth in broadband speeds (in %; 2007–2011).

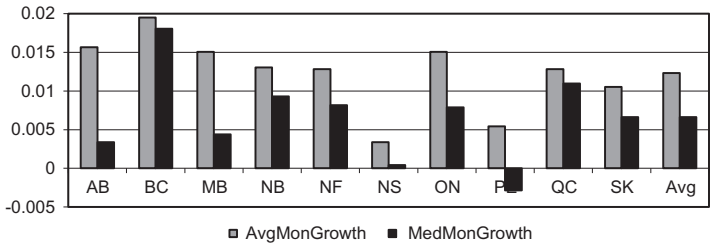

Fig. 4. Monthly change in network speeds (2007–2011).

average of Speedtest and Akamai estimates. According to this measure by 2011 British Columbia and New Brunswick had developed relatively high-speed broadband systems. Network speeds in Saskatchewan, Newfoundland, and Manitoba lagged behind other provinces.

5.2. Network performance growth: 2007–2011

Broadband speed measurements at a particular point in time are a function of past investments by infrastructure operators, their ability to manage existing resources, and end user demand for network resources. Consequently, it is difficult to use static measures to draw inferences about possible sources of variation in digital infrastructure development such as geography, demand intensity, market competition, and public policy. To better understand the impact of these factors on the development of high-capacity networks that are required for the diffusion of more advanced ICT applications, the rest of this section focuses on growth in network speeds over time across the provinces using measurements compiled from the logs of Akamai, 2011 servers from April 2007 to May 2011. This represents a period of substantial growth in residential broadband traffic and the data provide a basis for characterizing distinctive network development patterns in Canada.

Fig. 3 documents cumulative growth in average and peak connectivity speeds between the beginning and end of this period (using three month averages). Estimates of peak speeds represent the mean of highest connection speeds per IP address detected by Akamai servers over the course of a month. In contrast to average speeds which capture network conditions when most end users want to use the network (i.e. late afternoons and evenings; see Bauer, Clark, & Lehr, 2012), peak rates can be viewed as an indicator of network performance when end user demand for network resources is relatively low (i.e. after midnight). At the extremes, average Internet speeds in British Columbia more than doubled, while they remained the same in Nova Scotia. Although average speeds in Nova Scotia did not change, peak speeds nearly doubled. While average speeds in both Ontario and Quebec grew around 60%, in Ontario the increase in peak network performance was substantially larger than in Quebec (165% in Ontario versus 110% in Quebec). With the exception of New Brunswick which had the second highest performance level in 2011, provinces with relatively high-speed networks at the end of the period were generally those that experienced more rapid growth in network speeds in the preceding years.

To capture differences in network development patterns, Fig. 4 presents average and median monthly growth in average network speeds. Average monthly increases in speeds were relatively high in Alberta and British Columbia, and relatively low in Nova Scotia and Saskatchewan. Average monthly growth rates in network performance were generally higher than

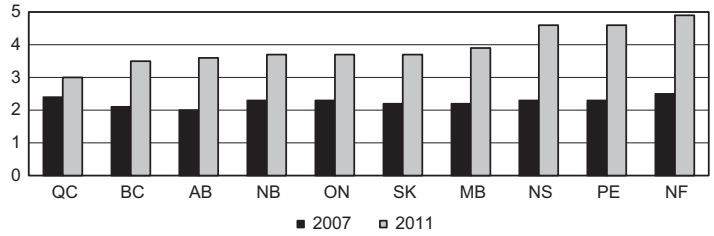

Fig. 5. Ratio of peak to average speeds.

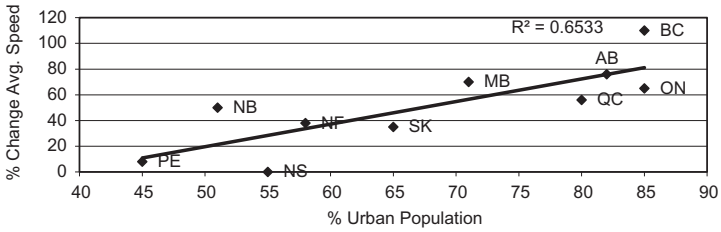

Fig. 6. Geography and performance growth.

median growth rates. The difference between average and median growth is particularly large in some provinces, including Alberta and Manitoba. This suggests that substantive improvements to the networks in these provinces were the result of a relatively small number of relatively large projects. In contrast, British Columbia and Quebec experienced a more even distribution of performance enhancing investments over time. Median monthly growth in connectivity speeds in British Columbia was nearly three times the average in other provinces.

Increasing demand for network resources associated with the diffusion of advanced ICT applications is apparent in the growing gap between average and peak performance in all provinces. The difference between the two indicators can be interpreted as a measure of slack capacity ISPs install in order to meet end user demand at times of the day most end users want to access the Internet. As end users adopted more network intensive applications, operators had to install relatively more excess capacity in the system to handle demand in peak traffic periods. Fig. 5 documents that between 2007 and 2011 the level of necessary "slack" in the Canadian network nearly doubled. With the exception of Quebec, the difference between average and peak speeds appears to have been relatively low in provinces that had higher average speeds in 2011 (e.g. British Columbia, Alberta, and New Brunswick). Although the size of the sample does not allow for statistically reliable inferences, this suggests operators in provinces with higher average performance might be better at managing the network capacity they have installed in the past.

5.3. *Determinants of network performance growth*

A wide range of interrelated factors influence the incentives of operators to invest in network capacity upgrades, including geography, demand intensity, competition from rivals, and public policy. Given the regional nature of competition in the Canadian broadband market (i.e. no single national incumbent, different cable and DSL operators in different provinces), different strategic objectives of various incumbents may also contribute to provincial variations in network development. This section explores a number of possible explanations for observed differences in patterns and levels of growth in the speed of Internet connectivity in Canada. Given the small number of provinces, it is not possible to separate different factors in a statistically meaningful manner. Nevertheless, the qualitative analysis provides a number of novel insights and can be employed as a basis for more rigorous studies in the future.

5.3.1. *Geography*

Canada's vast geography has often been employed to justify policies that reduce entry and competition in the provision of communications services (Babe, 1990; Winseck, 1997). However, today more than 80% of the Canadian population resides in a small number of relatively densely populated metropolitan areas near the U.S. border. This partly explains Canada's early success in terms of access growth and the relatively high level of platform competition from cable networks because in more urban countries the fixed costs of network capacity enhancement can be allocated across a larger number of end users. Nevertheless, low population densities and challenging terrains in more rural areas mean relatively higher fixed costs of upgrading network capacity and rolling out new technologies beyond urban areas. This reduces incentives to incur specific investments required for network capacity improvements. The potential for rural market failures help explain why public policy initiatives tend to target remote and rural communities. Higher fixed costs of upgrading infrastructure in less densely populated areas also suggest that incentives for improving network performance in rural areas tend to be lower than more urban jurisdictions. Fig. 6 documents the positive correlation between the degree of urbanization and growth in Internet connectivity speeds across the provinces.

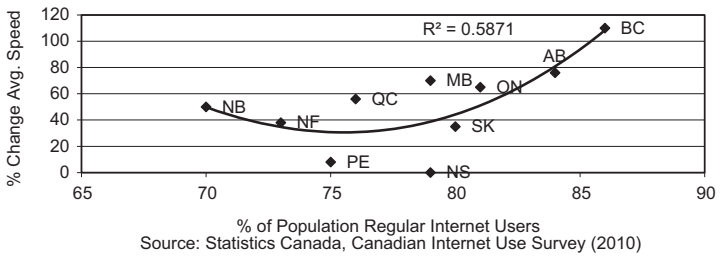

Fig. 7. Internet use and performance growth (Statistics Canada, Canadian Internet Use Survey, 2010).

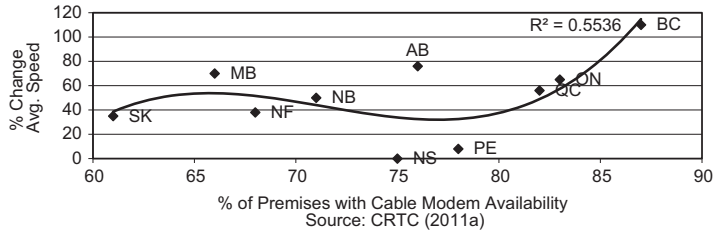

Fig. 8. Platform competition and performance growth (CRTC 2011a).

5.3.2. Demand intensity

When operators expect that particular communities are more likely to use the Internet more intensively, they are also more likely to invest in upgrades necessary to meet this demand. Use intensity is itself a function of more complex demographic and cultural differences. For example, older populations are more likely to employ the Internet for first generation applications such as email and simple web browsing. In rural areas subject to an outflow of young end users, operators have relatively weak incentives to invest in network capacity upgrades. On the other hand, if operators invested in very high quality networks, a larger number of end users would be able to deploy more network intensive applications such as multimedia and IPTV. Consequently, the direction of causality between supply and demand is theoretically ambiguous. Fig. 7 suggests a non-linear relationship between demand intensity and the growth in network speeds. While provinces with higher demand intensity have higher quality networks (e.g. British Columbia and Alberta), some regions with relatively high quality networks appear to exhibit relatively low levels of demand (e.g. New Brunswick). A more detailed analysis of the interaction between use and supply patterns is beyond the scope of this paper and will require future research attention.

5.3.3. Platform competition

Although the federal regulatory framework has been relatively ineffective in promoting service-based competition, there is significant competition between DSL and cable broadband providers (van Gorp & Middleton, 2010). The extent of platform competition varies across the provinces, partly as a function of urbanization. Consequently, it would be difficult to separate the impact of geography and platform competition on broadband outcomes given the small sample size. The highest degree of platform competition was in British Columbia, which also had the highest level of broadband performance improvements. However, relative to Quebec and Ontario cable modem availability was lower in Alberta which had the second highest rate of broadband performance improvements in the country (CRTC, 2011a) (Fig. 8).

5.3.4. Causality and public policy

As the discussion in previous sections highlights, it is not readily feasible to isolate the effects of different factors that shape network infrastructure development and pinpoint the direction of causality between geography, demand intensity, and platform competition on network outcomes. One reason for this is the small number of Canadian provinces, which suggests future research could help decompose the causes and effects of digital infrastructure development by extending the analysis to other federations to increase the number of data points. Even with a larger sample size, explanatory variables discussed in this paper appear to be highly interrelated, which would generate a complex multicollinearity problem for quantitative analysis of this issue. For example, geography influences the propensity of operators to invest in particular communities and determines if platform competition is viable. The links between supply and demand factors are also ambiguous, since higher levels of demand increase incentives for network deployment, but the availability of high-capacity networks enables end users to deploy advanced and network intensive ICT applications (e.g. multimedia, cloud computing, IPTV) and increases demand for network resources. Furthermore, there are other factors that might be important in shaping network development that are not discussed here, including firm level strategy and efficiency differences. For example, vertically integrated operators that provide telephone and TV broadcasting services might have relatively limited incentives to improve Internet connection quality because that would allow end users to bypass existing distribution channels and cannibalize current cash flow.

Nevertheless, the experience in Canadian provinces highlights the potential impact of different policy strategies on levels and patterns of network development:

- *Public ownership*: Saskatchewan has retained public ownership of the copper platform operator, a policy which is associated with relatively low levels of cable penetration and network performance improvement over time. Notably, platform competition is substantially lower in Saskatchewan than a number of less densely populated provinces in Atlantic Canada. This suggests public ownership can crowd out private investment in platform competition.
- *Rural subsidies only*: A number of provinces have been reluctant to adopt systematic policies that shape the market and have instead focused their policies only on initiatives that target market failures in rural areas. These include Ontario and Quebec where most end users reside and average network performance growth has been about average. Atlantic provinces also fall in this category, but they also have relatively low population densities and demand intensity levels, which are not conducive to high rates of network performance growth.
- *Direct investment in the Internet backbone*: Alberta has followed the approach adopted by a number of national governments elsewhere by investing public funds directly in an open access backbone that competes with incumbent infrastructure providers. While there is some controversy about the structure of Alberta's approach and the application of open access rules on the edge of the SuperNet, it is evident that the pace of progress in Internet connectivity improvements has been substantially above average. This is despite the fact that the level of platform competition from cable in Alberta is less than larger and lower performance provinces such as Ontario and Quebec, which have broadly similar urbanization rates.
- *Strategic procurement policy*: In contrast to Alberta which used its procurement power as a basis for justifying direct investment in an open access backbone, British Columbia has leveraged its demand for telecommunications and information services to co-opt the incumbent. Through a series of contractual arrangements the government has made its demand to commit the incumbent to cooperate with third parties that need access to essential transport and local facilities in the province. Although there are clear costs to long term procurement lock-ins, this approach is associated with highest rates of performance growth in the country, as well as a relatively normal distribution of network capacity improvements over time. Nevertheless, urbanization, demand intensity, and platform competition are also relatively high in British Columbia. This makes it difficult to ascertain the exact direction of causality between demand, public policy, and supply of Internet access services.

6. Summary and conclusions

Policy discussions and research on broadband network development over the past decade have focused primarily on increasing *access* to high-speed Internet connectivity. Policymakers have noted the potential for market failure in extending broadband access to less densely populated areas and tried to address the problem with private sector subsidies targeting rural communities. Research has also centered on broadband access levels and penetration rates as the key independent variables in studies that try to assess the impact of public policy on digital infrastructure development. As questions about geographic coverage of broadband networks are resolved in high-income countries, attention is increasingly turning to the impact of public policy on the *quality* of Internet connectivity. The Canadian experience with the development of broadband networks provides an instructive example of this shift in policy focus.

In the first stages in the diffusion of high-speed Internet connectivity, a relatively high degree of competition between operators of copper telephone and cable broadband networks enabled Canadian providers to expand broadband access relatively more rapidly than other advanced economies. However, the pace of progress in broadband quality improvements in terms of speed has been relatively slow and incentives to deploy next generation fiber-to-premises networks have been limited. These trends have led to concerns about regulatory barriers to international and domestic competition in the provision of Internet access services. Although policy review panels and academics have proposed substantive reforms that could promote competition and investment in the sector, these recommendations have been ignored and do not appear to be feasible. As a result there is increasing pressure on sub-national governments to design and implement decentralized policy solutions to increase the pace of progress in network development. Canada's federalist constitution, that makes the provinces responsible for delivering public goods such as healthcare and education which would benefit from having a high-quality digital infrastructure, increases the impetus for policy decentralization, experimentation, and differentiation.

This article contributes to the discussions by analyzing the impact of different policy approaches by Canadian provinces on the evolution of Internet connectivity. Public ownership of the incumbent operator was associated with a low level of platform competition and slowest connectivity speeds in the country. The pace of progress in connectivity improvements was lower in provinces that focused their policies only on addressing market failures in rural areas relative to governments that leveraged their demand for communications services to promote broadband network development. Using contractual arrangements to commit incumbent operators to open access policies and specific performance targets appears to have been more effective than direct public investment in the backbone infrastructure in expanding broadband access and quality. Nevertheless, both strategies are costly because they lock in sub-national governments to long term procurement contracts. Adopting a more stringent essential facilities regime at the national level might be a more cost effective option than co-opting operators with procurement contracts. This can reduce investment incentives of legacy platform operators, but might be required for enhancing market discipline and incentives for the adoption of next generation broadband technologies. Future research on the links between multilevel policies and digital infrastructure quality can help identify best practices and enhance broadband policy coordination across different levels of government.

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