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The Canadian Productivity Review

Infrastructure Capital: What Is It? Where Is It? How Much of It Is There?

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John R. Baldwin and Jay Dixon

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Abstract

This paper focuses on investment in infrastructure in Canada. The size of infrastructure investments relative to other capital stock sets this country apart from most other Organisation for Economic Co-operation and Development countries. The paper reviews the approaches taken by other researchers to define infrastructure. It then outlines a taxonomy to define those assets that should be considered as infrastructure and that can be used to assess the importance of different types of infrastructure investments. It briefly considers how to define the portion of infrastructure that should be considered 'public.' The final two parts of the paper apply the proposed classification system to data on Canada's capital stock, and ask the following questions: how much infrastructure does Canada have and in which sectors of the economy is this infrastructure located? Finally, the paper investigates how Canada's infrastructure has evolved over the last four decades, both in the commercial and non-commercial sectors, and compares these trends with the pattern that can be found in the United States.

Executive summary

Recent studies by Statistics Canada have focused on the importance of publicly owned infrastructure in the Canadian economy. Publicly owned infrastructure has also gained the attention of economists in other countries, who have asked how it supports growth and prosperity.

Despite the interest in public infrastructure, most papers in this area do not explicitly justify which assets should be called infrastructure or why a portion of infrastructure should be called 'public.'

Statisticians collect data that are meant to help inform debate. Classification is fundamental to this process of data collection. This paper asks whether there is a well-defined and defensible taxonomy that statisticians can use to organize their collection efforts to provide data on the capital that is invested in public infrastructure in Canada.

This paper first outlines problems in the present debate. It then proposes a taxonomy that can be used to assess the importance of different types of capital investments that researchers may consider infrastructure or the portion of the total that should be considered 'public.'

The paper starts by developing a classification system for the collection of data on infrastructure. While there is widespread agreement, in the existing literature on the functions of infrastructure, that it provides an important foundation required to support private investment and economic growth, quality of life and security, there is no universally accepted definition of what it actually is.

The second section of the paper proposes criteria for deciding which assets are infrastructure, and it summarizes the arguments that have been made as to why some infrastructure might be classified as 'public.'

When analysts do attempt to create a structure to help them define infrastructure, they commonly focus on functions of the products produced by industries in which infrastructure assets are located. We choose not to proceed in this direction, arguing that it is problematic for two reasons. First, it is difficult to obtain agreement on which functions are 'foundational' in the infrastructure sense. Lists that attempt to do so generally fail to establish any clear criteria as to what should be left out or what should be included. Definitions that refer to 'the public interest' leave the analyst with having to list areas where the public sector expends resources or where it legislates in the public interest. These areas vary, country by country and jurisdiction by jurisdiction, and therefore do not provide universal standards.

Instead, we define infrastructure as a set of assets possessing certain characteristics that give rise to specific economic problems that are pervasive across different economies. This approach relies on the economics of contract theory. In some situations, contractual problems lead to imperfect market outcomes like monopolies, which develop because of the characteristics of the production process that, in turn, are related to the nature of the capital assets that provide the foundation for production in these industries. In addition, the economic theory of contracts can be used to guide us in the choice of the characteristics of assets that create problems for the economic system—that either make for difficult and perhaps imperfect outcomes in the market system (natural monopolies) or that lead to public intervention.

We rely on certain physical characteristics of the assets (other than ownership) to define which assets should be classified as infrastructure. While we believe that clear criteria exist in this area for defining infrastructure assets, we conclude that coming up with convincing criteria that can be used to draw a line between what is private and what is public is difficult and probably brings a statistical agency into territory where it is inappropriate to tread. Furthermore, even if the distinction were clear in theory, existing data sources do not provide enough detail to draw it in practice. We thus construct a functional classification system that defines infrastructure but that will allow users to make their own judgements on where to draw the line between private and public infrastructure.

This paper defines infrastructure as a set of fixed structures with these specific characteristics—that have long useful lives, whose creation involves a considerable gestation period, that have no good short- to medium-run substitutes, that underpin the production of a flow of services, and for which it is difficult to maintain inventories. These assets also have a special foundational role, supporting other factors of production.

Fortunately, the existing collection systems of Statistics Canada already use a taxonomy that enables us to identify assets with these characteristics. They fall under the general category that we refer to as fixed structures—consisting of engineering structures and buildings; however, determining which of them have a foundational role is more difficult. Determining which of the structures have qualities that make them public in nature is an even thornier task. The latter requires an analysis of why the commercial sector cannot resolve the contractual problems associated with infrastructure assets that require public intervention to guarantee adequate supply. Since that is not the task of statisticians and its importance differs jurisdiction by jurisdiction, we forego any attempt to do so herein. We restrict ourselves to highlighting the main features of infrastructure assets in general and classifying each of the engineering and building assets as to whether they belong to infrastructure or not. We do not go beyond a discussion of the rationale used by others to argue that these assets may also be considered to be public in nature.

Since the characteristics associated with infrastructure assets are also often associated with government intervention, the fact that most structural assets attract government intervention suggests that many of these assets are candidates to be included in a definition of public infrastructure for this reason. That is, these assets do indeed have the characteristics that lead to contract failure—as evidenced by the amount of government intervention in these areas (see Baldwin 1989). Infrastructure tends to be long-lived, and thus takes a long time to build. It is inflexible in its use, and the services it produces have a low elasticity of demand. Their essential nature and their inflexibility often lead to contracting problems that create a demand for public sector ownership or involvement.

But although public sector involvement in some form is often a feature of public infrastructure, it is not a necessary or sufficient condition to designate an asset 'public infrastructure' as a result of contract failure. The government often owns or regulates for reasons other than the ones we have stated. Furthermore, since public sector involvement is often provoked by difficulties in writing contracts between private parties, it will depend on institutions (especially legal systems) that differ across countries and over time. Thus, in some countries, governments may be actively involved in certain sectors over certain periods of time; in other countries, governments take a hands-off approach to the same sector because the commercial sector is able to resolve contractual problems in the infrastructure arena. The physical characteristics that define infrastructure assets are only associated with contractual 'problems,' not with universal market failure.

We believe that a definition of infrastructure must be consistent, across jurisdictions and over time, in order to be useful. Therefore, we do not rely upon public sector ownership or government involvement in determining which assets are public infrastructure. Instead, we rely on the characteristics of the assets themselves that determine whether they are infrastructure.

We construct a dataset on infrastructure assets for Canada from 1961 to 2002, and find that the overwhelming majority of tangible, produced structural assets are located in the public sector and in a handful of other economic sectors—electrical utilities, transportation, communications and water. These commercial sectors produce outputs that either are, or traditionally have been, the subject of government regulation in terms of their quantity or price.

As our data show, whether one uses the assets, or the sectors in which they are found, to examine and define infrastructure, one ends up with a roughly similar picture. There are a small number of three- and four-digit North American Industry Classification System (NAICS) industries that have most of the assets that can be characterized as infrastructure. In fact, the only decision that has a significant impact on the data is whether to consider only public sector assets, or whether to consider assets in the small number of commercial sectors where these assets are concentrated. We argue for the latter measure, for reasons of cross-country comparability and time consistency cited above. However, we provide enough detail in our dataset to allow for alternative interpretations. We prefer the asset route because it allows us to provide a picture of the importance of infrastructure across the entire economy, not just in those industries where most of the infrastructure is found.

Another useful feature of the method used here is that most of the engineering construction assets and many of the buildings can be classified by function. In this paper, we adopt a specific mapping that allows us to describe which of the assets are devoted to transportation; communication; electricity; waste, water and sewage; natural gas and oil distribution; public safety; defence; education, recreation and culture; and health and social protection. This functional classification system is derived, with minor modifications, from a mapping that we propose from asset types to the Classification of Expense by Function of Government (COFOG) that permits us to examine infrastructure, not just by industry classification but also by purpose in the economy. Transportation, electricity and water make up most of the engineering infrastructure outside of mining.

The functional breakdown has two applications. It allows us to ask whether the patterns displayed by infrastructure are a function of changes in the economy, or of changes in specific sectors. It also allows us to specify different relationships between different types of infrastructure. It is likely, for example, that transportation performs a different function in the economy than sewage treatment. Distinguishing between the roles of the various types of infrastructure should thus help empirical enquiries into the nature of infrastructure's role in supporting other factors of production.

The paper's main purpose is to propose a rigorous definition of infrastructure and to provide the facts on the amount of infrastructure in Canada. It does not address the adequacy of the present state of the infrastructure stock. But it does examine the evolution of Canada's infrastructure capital since 1961. In doing so, it examines the role of infrastructure relative to general economic activity. It is important to recognize that infrastructure is just one of several types of capital and to ask how changes in infrastructure compare with changes that have occurred in other factor inputs (capital and labour). In this regard, the paper compares trends both in the commercial and the public administration sectors to see whether use of infrastructure differs in the public and private sectors.

Canada's total capital stock was roughly steady relative to output until the mid-1990s, after which it declined slightly. The drop was led by a relative decline in engineering construction, which stopped growing in the 1980s. The output-to-capital ratios of building construction remained roughly steady while that of machinery and equipment increased. In combination, the relative stability of total capital, along with increases in the shares of machinery and equipment and declines in engineering capital, are consistent with changes in relative prices over time that have made the former relatively less expensive than the latter and has led to substitution among different forms of assets. That this substitution also occurred in the United States indicates that similar forces were at work within the two economies.

The study also compares Canada's long-term infrastructure growth history with that of the United States. The period from 1960 to 2000 divides into two approximately equal periods. Prior to 1980, gross domestic product (GDP) and capital grew more quickly in Canada than in the United States. The relative performance in Canada slowed thereafter. But the slowdown in spending on structures was only part of the overall slowdown. The spending on machinery and equipment in Canada slowed even more than that on structures.

Since changes at the level of the economy can hide differences within sectors, we also examine the changes that occurred within the public sector and certain other infrastructure industries.

The relative decline in engineering construction in the aggregate economy is not—with the exception of the transportation sector—due to the relative decline in the importance of the goods and services these sectors produce, but because almost all these sectors are using less engineering construction to produce their output.

The within-sector decline could be due to one of three reasons. The first possibility is that these sectors have invested too little, and are producing higher output by working their infrastructure too hard, thus wearing it out. The second possibility is that firms have substituted other types of capital (i.e., machinery and equipment) and labour for infrastructure capital. The third possibility is that the firms in these sectors are making better use of their infrastructure capital. It could mean that these firms have found ways to use their existing capital better. Alternatively, they may in the past have built excess capacity in anticipation of higher future demand.

Given that the downward trends in infrastructure-to-GDP ratios have persisted over a long period of time (almost 20 years) and are consistent across infrastructure sectors, the first possibility seems unlikely. Moreover, the Canadian trends were broadly duplicated in the United States. A more plausible explanation is that firms in these sectors have become more efficient in using their capital, either because they started from a position of over-capacity or because they have increased their productivity.

With regards to the public sector's infrastructure, its importance in the economy (infrastructure capital relative to total GDP) has been declining steadily since the early 1970s, in spite of the increase in the public sector's share of output until 1993. This trend can be found in both Canada and the United States. This is due to an increase in expenditures on labour in the public sector. In a sense, public administration is becoming more of a service sector, and requires relatively less infrastructure capital and more labour services to produce the output that is being demanded of it.

While infrastructure capital has been declining relative to other forms of capital, it has not declined in relative terms, compared with the population that it is servicing. Indeed the amount of public sector infrastructure capital per capita has been relatively constant over the last 20 years.

In conclusion, infrastructure assets not only have characteristics that differentiate them from other types of capital, but their usage patterns distinguish them from other assets. They are highly concentrated in a small number of sectors that are either non-commercial or where there is either regulation or substantial public ownership. Moreover, the growth pattern of these assets has followed quite a different trajectory than other assets over much of the last 40 years. Whether in the commercial or the public administration sector, these assets have grown considerably slower than other assets.

1 Introduction

Recent studies by Statistics Canada have focused on the importance of publicly owned infrastructure in the Canadian economy. Harchaoui and Tarkhani (2003) examine the extent to which certain types of capital (engineering assets such as roads, sewers, etc.) in the public sector (what they call public infrastructure) have spillovers on the performance of the private sector—the extent to which it reduces private sector production costs. Larger amounts of publicly owned engineering assets were found to reduce production costs in the private sector.

Publicly owned infrastructure has also gained the attention of economists in other countries, who have asked how it supports growth and prosperity. Their studies have generally found that investments in these areas contribute to a country's economic performance and quality of life.[1]

Discussions about infrastructure have focused not just on the importance of this asset but also on its adequacy. Some observers have argued that public infrastructure is showing signs of strain.[2] Policy-makers have become increasingly concerned about congested roads and crowded airports.

Investments in engineering assets can also be found in the commercial sector—in the form of railways, pipelines, communications towers and lines, dams and generating plants. These foundational assets are prevalent in many parts of the commercial sector. Baldwin et al. (forthcoming) compare the Canadian and U.S. economies and find that these assets make up a considerably larger proportion of total capital in Canada than in the United States. Canada relies more on 'infrastructure' investments in the private sector than does the United States.

Despite the interest in public infrastructure, most papers in this area do not explicitly justify calling some assets infrastructure or explain why a portion of infrastructure should be called 'public,' thereby suggesting they have a special role or a call on the public purse. In some cases, papers concentrate exclusively on publicly owned capital; others simply provide a list of the areas they consider critical infrastructure, whether it be in the public or private sector, without providing justification for the items in it.

The absence of an agreed-upon definition creates a problem, both for researchers attempting to evaluate the impact of infrastructure and for policy makers trying to decide how much and where to invest. How can we discuss the state of infrastructure if we do not know exactly what it is?

Statisticians collect data that are meant to help inform debate. Classification is fundamental to this process of data collection. This paper asks whether there is a well-defined and defensible taxonomy that statisticians can use to organize their collection efforts to provide data on the capital that is invested in public infrastructure in Canada.

This paper first outlines problems in the present debate. It then proposes a taxonomy that can be used to assess the importance of different types of capital investments that researchers may consider infrastructure or the portion of the total that should be considered 'public.'

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1. See Aschauer (1990) and Harchaoui and Tarkhani (2003).
2. Ford and Poret (1991).

In doing so, it adopts the stance that, in the absence of a theory about infrastructure's role in the economy, it is difficult to come up with an all-encompassing definition. Furthermore, because different types of infrastructure may influence the economy differently, there is likely no single definition that suffices for all uses. The needs of users will differ sufficiently to require variants that are tailored to suit special needs. But variants, if they are to be useful, need to be easily related to one another, if only so that they can be compared side by side. And therefore the purpose of this paper is to provide a set of alternatives that fit together to provide an exhaustive picture of the whole.

The following section evaluates the existing literature on infrastructure. It confirms that, while there is widespread agreement that infrastructure is important for private investment, economic growth, quality of life and security, there is no universally accepted definition of what it is. Researchers tend to analyse ad hoc lists of assets that they consider to be infrastructure. Definitions of what constitutes the public portion of infrastructure are equally vague. Some make no distinction between publicly owned capital and public infrastructure. As a result, they may miss important public-infrastructure assets owned outside the public sector. These omissions may become more likely now that governments are increasingly involving the private sector in public investments.

The second section of the paper proposes criteria for deciding which assets are infrastructure, and summarizes the arguments that have been made as to why some infrastructure might be classified as public. We rely on certain physical characteristics of the assets (other than ownership) to define which assets are infrastructure. While we believe that clear criteria exist for defining infrastructure assets, we conclude that coming up with convincing criteria that can be used to draw a line between what is private and what is public is difficult and probably brings a statistical agency into territory where it is inappropriate to tread. Furthermore, even if the distinction was clear in theory, existing data sources do not provide enough detail to draw it in practice. We therefore construct a functional classification system that defines infrastructure, but that will also allow users to make their own judgements on where to draw the line between private and public infrastructure.

In the final two parts of the paper, we apply the classification system to data on Canada's capital stock and ask the following questions: How much infrastructure does Canada have? In which sectors of the economy is this infrastructure located? Do our answers to these questions depend on our classification system? We conclude that the majority of assets with characteristics of infrastructure are found in a handful of industries. The implication of this finding is that research on infrastructure will not be highly sensitive to the method of classifying infrastructure—by function as opposed to industry.

Next, we investigate how Canada's infrastructure has evolved over the last four decades. The evidence shows that, after increasing in the early part of the period, the stock of engineering construction and buildings that we have selected as candidates for infrastructure has declined in importance over the past 20 years. It has fallen as a fraction of gross domestic product, and it has levelled off in real per capita terms. These measures may indicate that we have under-invested in infrastructure. Alternatively, it may indicate that we have become more efficient with our capital investments. However, the fact that the trends in the public sector mirror trends in the commercial sector indicates that all infrastructure investments are following a common trend. Moreover the tendencies in these areas are for the most part very similar in Canada and the United States. This suggests changes in infrastructure are responding to quite similar forces in the two countries.

2 Public infrastructure: A brief review of the literature

The term 'infrastructure' is defined in the Oxford English Dictionary (1989, VII: 950) as "…the subordinate parts of an undertaking; substructure, foundation; *spec.* the permanent installations forming a basis for military operations, as airfields, naval bases, training establishments, etc."[3] It was coined in a military context, as the definition suggests, but it gained popularity in the area of economic development in the 1950s.

Concerns about the state of 'public infrastructure' in the Organisation for Economic Co-operation and Development (OECD) are a more recent phenomenon. The attention it has garnered in the public policy arena and in economic journals is a reflection of concerns about the adequacy of existing levels of infrastructure that is considered to be public—probably because these are so dependent on political decisions that may not always take the economic consequences into account. Economic studies and engineering assessments in much of the OECD assert that infrastructure is both economically and socially important, and they worry that the existing stocks may not be up to the task that is expected of them.

2.1 The importance of public infrastructure

A taxonomy of public infrastructure must first construct a definition of what is to be included under the category 'infrastructure' and then whether the asset deserves to be classified as 'public infrastructure.'

Discussions of public infrastructure rarely start with straightforward definitions of what infrastructure is but rather with a general discussion of what it does. The literature cites three reasons why an adequate supply of infrastructure is important: it supports economic growth, it enhances quality of life and it is important for national security.

Economist David Aschauer recently rekindled the economics profession's interest in infrastructure in the United States with a series of papers asserting that investment in the public sector not only improved quality of life, but it also increased economic growth and improved returns for private investments. Aschauer's work suggested that the impact of public investment on the economy was large—too large to be credible according to many economists—with rates of return of 50% or higher.

3. The *Nouveau Petit Robert* (1993, 1362) refers to infrastructure as "the foundation—the underlying earthwork and structures that contribute to the construction of platforms for railways,...and the ground installations (runways, buildings, radio transmitters, etc.) [for airfields]. [Used in a military context]...All the installations necessary for the activities of the armed forces in a territory." (TRANSLATION).

Some economists disputed Aschauer's methodology, but his findings created a new interest in infrastructure investment made by public authorities. Many economists speculated that the drop in infrastructure investment could explain the slow growth in productivity in Europe and North America during the 1970s and 1980s. They suggested that more spending on public infrastructure might spark a new 'golden age' of growth and prosperity, like the one North America and Europe experienced in the decades following the Second World War.

Beyond its utility to growth, however, public infrastructure is also seen by advocates to underpin the quality of life. Aschauer begins his discussion on why infrastructure is important with a discussion on its impact on quality of life. Better roads reduce accidents, so improving public safety. Water systems have reduced disease. Waste management improves health and reduces unpleasant odours. Infrastructure is thus important not only for the economic benefits it brings, but also because of its impact on, *inter alia*, health, safety, leisure and general aesthetics.

The third aspect of public infrastructure, and the one that makes it especially important to policymakers, is its impact on national security. As President Clinton's Commission on Critical Infrastructure Protection stated in 1996:

"Certain national infrastructures are so vital that their incapacity or destruction would have a debilitating impact on the defence or economic security of the United States. (…) Because many of these critical infrastructures are owned and operated by the private sector, it is essential that the government and private sector work together to develop a strategy for protecting them and assuring their continued operation." (Federal Register 1996)

With this definition, the definition of infrastructure moves outside of what is just owned by the public sector to that which is also produced and owned in the private or commercial sector.

The OECD has recently embraced this extension. An assessment of the long-term trends for infrastructure investment for the OECD's *Futures Project on Global Infrastructure Needs* includes a section on its 'geo-political impacts.' Noting public infrastructure's 'dual uses'—civilian and military—it argues that public infrastructure can be important in, for example, providing access to critical 'strategic resources.' It also suggests that it has the potential to reduce political risk of exposure to the global economy and foster cooperation across countries.

2.2 Attempts to define public infrastructure

Unfortunately, researchers trying to assess the state of public infrastructure have been confronted with an awkward fact that "no universally accepted definition of infrastructure exists. Neither is it always clear what circumstances justify its public provision, subsidization, or regulation." (Vinings and Richards 2001, 1)

For the most part, the literature on public infrastructure deals with this problem by ignoring it. Most researchers are content with choosing what they feel to be a representative list of assets, without being very precise as to what makes those assets public, or even infrastructure. In the case of deciding what is infrastructure, the problem is not so much in deciding what assets should be included: "few dispute that roads, railroads, seaports, and airports are infrastructure," (Vinings and Richards 2001, 1) but on deciding what may be neglected, and why. In the case of decisions as to what part of infrastructure should be defined as public, the problem is that the debate is either trivial because it is merely a tautology—'public is what public does'—or the debate is extremely complex in that it involves a normative exercise that attempts to delineate the criteria that should be used to justify public intervention.

So, for example, the OECD's *Futures Project on Global Infrastructure Needs* lists assets covering water distribution, power generation and distribution, gas production and distribution, roads and railways, and telecommunications. But it gives little justification for its focus on just those areas. Papers at the World Bank offer assessments of the 'kilometres of roads' or 'number of telephones per 100,000 households,' in developing countries, but little or no discussion as to why they have chosen these measures.

In the United States, the American Society of Civil Engineers (ASCE) considers a more comprehensive list of infrastructure when compiling its annual "report card for America's infrastructure" (ASCE n.d.). It gives grades on infrastructure for aviation, bridges, dams, drinking water, energy, hazardous waste, navigable waterways, public parks and recreation, rail, roads, schools, security, solid waste, transit and wastewater. Again, however, the report card does not explain what these areas have in common that makes them of singular interest to the ASCE.

Other studies skirt the problem by focusing on ownership, implicitly defining publicly owned capital as public infrastructure—thereby simultaneously solving the problem of specifying both what constitutes infrastructure assets and what is public. For example, a conference in 1990 sponsored by the Federal Reserve Bank of Boston asked whether there was a shortfall in public capital investment; but, as one of the conference participants, Richard Musgrave, noted at the time, "…the session subtitles all refer to various aspects of infrastructure investment. Are we to conclude that all infrastructure investment is public, and that all public investment is infrastructure? This is hardly the case." (Musgrave 1990, 65.)

Indeed, it is increasingly not the case because governments have been inviting the private sector to participate in providing services in areas that were previously dominated by public sector. One reason for this is the private sector is often seen as a more efficient provider of infrastructure. It has been argued that the political process may not have the correct incentives to design optimal infrastructure systems—ones that minimize total costs of both initial investments and long-term maintenance. In this case, some form of public–private partnership may be chosen to improve these tradeoffs, with the government usually remaining involved in some form, most often through oversight and regulation.

2.3 The scope of assets considered as public infrastructure

Much of the literature referenced above focuses exclusively on produced physical assets. Some researchers who have thought about what constitutes public infrastructure raise the concern that the focus on produced physical capital misses other important forms of capital, specifically, environmental, institutional and social/cultural capital.

Some make the case, for example, that at least some environmental capital should be classified in the definition of public infrastructure. The Canada West Foundation argues that environmental capital in cities, or "[u]rban natural capital—everything from wild areas and water resources to soccer fields and community gardens—pays psychological, physical, and financial dividends that greatly improve the lives of urban residents and help sustain the long-term economic prosperity of our cities. We benefit from urban natural capital in a variety of ways including better health, greater social cohesion, richer urban cultures, cleaner air and water, more recreation opportunities and improved urban aesthetics. Urban natural capital is also a key to attracting tourism revenue and skilled labour, and increasing property values." (Wilkie and Roach 2004, 1)

It might therefore be argued that physical but non-produced environmental capital should be included as part of public infrastructure. If one is interested in infrastructure to improve the quality of life, then why are sports facilities public assets but hiking trails are not? Swimming in public pools and hiking in national parks are both forms of exercise. The man-made barriers that failed to defend New Orleans during Hurricane Katrina are part of public infrastructure. What about the marshlands that might have defended the city if they had not been cleared to make way for development? Levees and marshlands both stop flooding. If they serve the same function, why should they not both be considered infrastructure?

But why stop with physical assets? Vining and Richards (2001, 2) state "an increasing number of commentators recognize, however, that an exclusive focus on physical [produced or non-produced] infrastructure may still be too narrow, no matter how broad the scope of the facilities included…[i]nvestments in, for example, general purpose education and training may well be as important as investments in airports and highways."

Similarly, Musgrave (1990, 68) states that "physical assets are but part of the problem. Human investment in health and education may be no less important…and cannot be excluded from a more comprehensive analysis. Going even further, the very existence of the state, the judicial system and, for that matter, the prevailing work ethic are important features of the overall environment … and may be said to provide its infrastructure." Discussions of social capital implicitly embrace the notion that there are intangible community building assets that help to bind countries together.

The literature has had to face two difficulties when considering how to incorporate environmental, institutional and social/cultural capital into conceptions of public infrastructure. The first issue involves the well-known practical difficulties of measuring non-produced and intangible assets. But the second issue is the lack of a clear and concrete definition of what public infrastructure is. The difficulties researchers face when distilling the public infrastructure component of the physical capital stock carries over to these other forms of capital.

3 The need for a definition of public infrastructure

Before embarking on an attempt to define public infrastructure, we should ask whether we need a definition. After all, there is already a definition of public infrastructure in widespread use. It could be called the 'Casablanca definition' of public infrastructure, after Supreme Court Justice Potter Stewart's concurrence in a pornography case:[4] although unable to define 'pornography,' he asserted "I know it when I see it."

For statisticians who are partial to definitions that set clear, well-defined boundaries, this is not a very satisfying definition. It seems, however, to work well for many applications and many economists, engineers and policy-makers use it. A review of papers on public infrastructure from all three of their respective literatures yields different yet overlapping lists of assets. Usually, virtually no mention is made of how those assets were selected, and little to no concern is expressed as to whether the lists are exhaustive. But if researchers are not bothered by the imprecision of the existing definition, why should statisticians be?

The problem with an ad hoc definition is its potential to cause confusion among researchers of public infrastructure. The literature reveals some confusion on what distinctions, if any, to make between, for example, public capital and public infrastructure. There is also a tendency for studies to either lump infrastructure's constituent parts together into one homogenous category, or to study one type of infrastructure (usually transportation) and ignore substitution possibilities or complementarities among different types of infrastructure.

The second problem is that advances in our understanding of what makes economies grow and societies prosper has expanded to include different forms of capital. It is becoming increasingly fashionable to speak of tangible, but non-manufactured environmental capital and intangible human and social capital. Just as conventional capital has a sub-category known as infrastructure, might these other forms of capital also have such a sub-category? But how can we define the boundaries of this sub-category, if we have trouble doing so for more familiar forms of capital?

Thus, although many researchers will be satisfied with ad hoc definitions, economic research and public policy discussions may benefit from the clarity provided by a more precise, standardized definition.

3.1 The Casablanca definition

The Casablanca definition usually consists of the following areas of infrastructure: transportation, communication, water and sewage, and electricity. Sometimes schools and hospitals are added to this list of 'core assets.' Courthouses and prisons also sometimes make the lists. More expansive attempts to define infrastructure make reference to environmental and human capital, although what aspects of them should be included and why are often left vague. All these lists raise, but fail to answer, the question as to what makes these assets, and not others,

4. Jacobellis versus Ohio. 378 U.S. 184, 194 (1964).

public infrastructure. Are they public infrastructure because they are so often the focus of the public sector? Or do they warrant public sector attention because of the qualities that make them public infrastructure?

The following sections address these questions by considering the common characteristics binding areas commonly considered to be infrastructure. It first considers what makes infrastructure capital assets 'infrastructure.' The key characteristics of infrastructure stem from their fixity—they are long-lived capital assets that provide a stream of benefits over time and states of nature.

The second part of this section then deals with trying to specify what constitutes public infrastructure. It considers three possible routes that can be used by statisticians to define the public portion of infrastructure: by aligning public infrastructure and the public sector, by linking public infrastructure and features of goods and services that are often thought to require public sector involvement, and by linking public infrastructure and a particular definition of the public interest.

The first route implicitly considers public capital and public infrastructure as being synonymous. The second route assumes that public infrastructure can be defined by instances of market failures (arising from externalities, natural monopoly or non-excludability) that demand or invite public sector intervention. The third route assumes that public infrastructure should be characterized by the services it provides to the public, irrespective of whether the public sector is involved, or whether the market will fail to provide them optimally, and arbitrarily defines some services as falling within this ambit.

3.2 What is infrastructural about infrastructure?

There are few compelling reasons to depart from the strict dictionary definition of infrastructure according to the Oxford English Dictionary (1989), as mentioned in the literature review, as "the subordinate parts of an undertaking; substructure, foundation; *spec.* the permanent installations forming a basis for military operations, as airfields, naval bases, training establishments, etc."

The definition implies that infrastructure plays a critical foundational, sub-structural and subordinate role. We suggest that this definition implies that these foundations have a number of basic characteristics. A foundation is a long-lived capital asset. This implies we should base a definition of infrastructure on fixed capital assets that have a high degree of permanency. In economic terms, this implies that the assets have a long length of life.
The assets also tend to have long gestation periods. The short-run substitution possibilities are relatively limited. These two characteristics make their destruction or any interruption in their services particularly disruptive or critical to the industries that rely on them. Assets that can be quickly replaced by rebuilding them or moving to alternative assets do not have these problems.

While we start by focusing on the nature of the asset, the character of the product that is produced by the asset is also important. Infrastructure assets are seen to be critical because of potential supply disruptions in the products they produce, should failure in the underlying assets occur. But a supply disruption is less of a problem for those industries producing products that can be held in inventories as a precaution against supply disruptions. For them, a well-functioning economic system has ways to mitigate potential supply disruptions. The same ability to maintain inventories, does not, however, extend to service industries like transportation, electrical power generation, and communications.

As an aside, these aspects of infrastructure have important implications for the level of infrastructure investment, and provide a potential rationale for government involvement. In addition to producing a flow of goods or services over time, they also do so over states of nature. In its latter role, infrastructure acts as a 'real option' to mitigate risk. Because the consequences of a disruption in infrastructure are thought to have particularly damaging effects, the real option nature of infrastructure becomes particularly important.

All economies face risk, and economic actors devise ways to mitigate that risk. But the characteristics of infrastructure assets are particularly bound up with types of risk that have widespread consequences for economies and that have made them the object of public interest.

Infrastructure offers options to society which finds some type of risk costly. The goods and services that infrastructure provides cannot be easily inventoried in the quantities one expects to require. Infrastructure provides real options that are most valuable when the flow of goods and services is inextricably linked to the capital asset and where unforeseen, potentially disruptive events may impact services.

Another characteristic that distinguishes infrastructure capital from other capital is its sub-structural, subordinate or supporting role. In order for infrastructure to have value as a special classification, we must consider what makes it distinct from other forms of capital. We suggest that infrastructure capital is thought to be an especially valuable form of capital because it provides indirect support for other factors of production, and goods and services, and not just because it is directly involved in producing goods and services.

Thus, we can divide capital assets into capital that combines with labour to produce capital or intermediate goods, capital that combines with labour to produce final goods and services, and infrastructure capital that combines with these other forms of capital (e.g., roads with trucks) and improves their productivity. The lines between the three types of capital are difficult to draw, particularly because so little of the theoretical work required to do so has yet been done.

The above discussion suggests we focus our inquiry on assets with certain specific characteristics:

1. They involve structures that have long, useful lives.
2. Their creation involves a considerable gestation period.
3. The assets have few substitutes in the short run.
4. These structures provide a flow of goods and services, for which it is difficult to maintain inventories.
5. The assets are important primarily because they are complementary to other goods, services and/or factors of production.

3.3 Other conceptual issues: The full scope of infrastructure capital

The economics profession has exhibited increasing interest in the accumulation of forms of capital other than tangible produced capital as an explanation for economic growth. Research on the determinants of the wealth of nations has led to concepts such as intangible human capital and social capital, as well as tangible but non-produced environmental capital. It seems logical that if infrastructure is a subset of capital assets, then these other types of capital have a subset that, like tangible produced capital, deserves the appellation 'infrastructure.'

The table below provides a classification of forms of capital based on whether or not they are produced and whether or not they are tangible. Physical capital is tangible and manufactured. Environmental capital is tangible, but is naturally occurring, not manufactured. Social/institutional and other capital is intangible, and may or may not be produced.

Types of capital→ ↓	Produced	Non-produced
Tangible	Physical structures	Environmental
Intangible	Social/institutional and other	

As appealing as this more inclusive taxonomy is, this paper will reserve the term infrastructure capital for physical, produced capital. Because we have as yet no precise definitions that describe intangible forms of capital, precisely delimiting and valuing that portion of them that is infrastructure is unfeasible. Environmental capital can be described with greater precision, but it is much more difficult to value, although we have made advances in measuring it. In contrast, we have many ways of describing and valuing tangible produced capital, so it is much easier to identify the boundaries of the subset referred to as infrastructure. We therefore confine our discussion to these types of capital assets.

3.4 Infrastructure assets

To lend concreteness to the discussion of physical infrastructure, we list the assets that are candidates to be considered as physical public infrastructure capital. Investment can be classified into three broad groupings—machinery and equipment, buildings, and engineering construction. Machinery and equipment are generally housed in structures and can generally be removed without substantially altering the structures in which they are housed. They include automobiles, computers and software, motors, generators and transformers, and capitalized tooling expenses. Buildings are free-standing structures—manufacturing plants, office buildings, warehouses, shopping centres, buildings with accommodation units, railroad shops, aircraft hangars and farm buildings. Note that the value of buildings generally includes machinery and equipment that is an integral part of the building (e.g., elevators). Engineering construction includes dams; non-building industrial works, such as refineries; highways, roads and streets; bridges; sewers; power and communications transmission lines; and similar structures and works. It sometimes includes buildings and machinery and equipment that are an integral part of the engineering construction.

Of the three classes of physical (tangible) produced capital assets (machinery and equipment, engineering construction and residential buildings), only the assets in the latter two categories qualify as permanent installations or foundations.

Machinery and equipment are movable assets, with relatively short lives (less than 15 years on average),[5] and are often bought and sold on second-hand markets. The first two characteristics mean that they mostly do not meet the 'foundation' requirements outlined in the previous section. The third characteristic suggests that they can be readily transferred or adapted to other users or uses. The fact that they are often not fixed in place or in purpose means that they do not meet the dictionary definition of infrastructure.

By contrast, engineering assets, including pipelines, rail lines, communications cables and towers, dams, power generating stations, highways and roads, are fixed in place and are long-lived (some 28 years).[6] These assets also generally involve expenditures that are considered as sunk costs once made, with low-resale value relative to original cost. The economics literature details the reasons for the much greater economic risk that investors face in these situations. Should unforeseen circumstances such as shifts in demand occur, the asset values will be almost entirely lost since they cannot be transferred to other uses. And the fact that investments are sunk means investors can be held hostage in bargains and contracts. And the long life of the asset means that the relatively high uncertainty of events that are far removed in the future makes investment decisions especially risky. All this raises the cost of capital that is invested in risky infrastructure investments, which in turn may reduce the availability of adequate amounts of this type of capital.

Buildings and structures used to house manufacturing facilities, shopping malls, hotels and commercial office facilities are also immovable and have long lives (28 years on average).[7] Unlike engineering construction, however, many buildings can be resold and used for other purposes—though often with substantial losses because of refurbishing costs required by the new purchaser. Buildings, therefore, fall between machinery and equipment and engineering assets, in terms of the proportion of their costs that are 'sunk.'

The next question is whether to include in the definition all infrastructure engineering construction and all buildings, or just a subset of them. Taking all the assets in these categories has an obvious appeal: it is simple. However, implicit in most economists' discussion of infrastructure is that it has special characteristics that make it a subset of capital assets. These characteristics are related to its sub-structural role, or its complementarities to other assets. But economists rarely specify exactly what the nature of these complementarities are, so deciding which of the long-lived assets has more of a sub-structural role becomes problematic.

5. See Statistics Canada (2007).
6. Ibid.
7. Ibid.

As a first approximation, therefore, we take all assets that fulfill our criteria. Engineering assets fulfill all of the criteria outlined in Section 3.2. They have very long lives; they have long gestation periods; and they have few substitutes in the short run. Their disruption has dramatic consequences upon very large segments of the economy: witness the impact of electrical power shortages.

On the other hand, machinery and equipment rarely fulfill these criteria, as noted above. Buildings, on the other hand, fall somewhere in the middle. They have longer lengths of lives than machinery and equipment. They cannot be built quickly, that is, they have long gestation periods. But in many cases, alternatives exist that permit substitution quickly. When the World Trade Center towers were destroyed in New York, tenants in the downtown office buildings that were affected were able to find alternatives long before the subway core was restored.

Not all buildings have close substitutes: complaints about prisons and schools being overcrowded suggest that they have few close substitutes that can satisfactorily handle demands that exceed capacity. In addition, buildings do have other characteristics that suggest some of them may be part of infrastructure—that of providing a complementary type of capital on which other inputs rest. The effectiveness of the equipment of a manufacturing firm depends in part on the buildings surrounding it.

In this paper, we consider all engineering construction and all buildings together and refer to them jointly as structures. We also divide them into functional groups by asset type. The full list of assets is given in Appendix A.

4 Defining the 'public' in 'public infrastructure'

The word 'public' in 'public infrastructure' has different possible connotations. It is used variously to connote the public sector, public goods and the public interest. The first usage defines public by the presence of the public sector, either as an owner/operator or as an active participant. The second and third define public in terms of the nature of the goods and services and the people consuming them (the public), respectively.
In this section, we consider whether there is a compelling argument for a statistical agency to adopt one of these definitions.

Those who restrict themselves to the first definition need only consider what is owned by the government. Those who use the second and third definitions are either trying to posit an explanation for what the public sector does or are trying to develop criteria for establishing what it should do.

While there should be overlap between public sector involvement and public goods, and public sector involvement and the public interest, there are no guarantees that the public sector will provide all the public goods that society requires.

While there are many reasons that public infrastructure may take on the character of public goods, or that its provision suffers from other forms of market failure, we will argue that market failure is a consequence of public infrastructure's other characteristics, rather than a defining feature in and of itself. It is those features that make public infrastructure what it is. We examine the arguments for using public sector, public goods and public interest for classification purposes below.

4.1 Public sector

The word 'public' often brings to mind the 'public sector,' that is, the government. There are two ways in which the public sector might be involved in public infrastructure. The first, and most common, is outright public sector ownership. The second is through public sector involvement. One variant of this involves an oversight of the industry via regulation—either rate-of-return regulation, restrictions on entry or price regulation. Another variant involves public–private sector partnerships, which involve a number of different types of contractual arrangements. In these cases, although the government does not own or run public infrastructure, it is heavily involved in the outcomes of the infrastructure industries.

4.1.1 Public sector ownership

One commonly used approach is to define government-owned assets, or a subset of them, as public infrastructure. Studies on the impacts of public infrastructure frequently use just publicly owned capital. This approach is easy to implement, but its simplicity comes at a cost. Although much of what is commonly referred to as infrastructure is public sector owned and operated, many governments around the world have privatized some public sector assets, or have entered into partnerships with private firms to manage them. Confining public infrastructure to the public sector will miss these assets. Analysts who want to capture all assets that provide foundational support to economic activity will not be able to do so with datasets based on this definition.

4.1.2 Public sector involvement

A broader definition would include more than just publicly owned infrastructure. One alternative would be: 1) that which is owned or operated by the public sector; 2) that for which government has a substantial regulatory role—defined by some threshold for the level of intrusiveness of regulation—or for which a substantial number of funds (defined by some threshold) for construction or operation, through subsidies, loans or direct investments come from the public sector; and 3) that for which for other reasons—possibly security—in which government is interested. This definition would include public and private capital as public infrastructure, provided it appears in a sector that is subject to a substantial level of public sector involvement.

It should be noted that most of these classifications offer challenges to statistical agencies because they would involve collection of data on the nature of contractual arrangements and oversight arrangements between the state and the private sector.

4.2 Public goods (and other market failures)

The definition of what is 'public' infrastructure sometimes involves judgements about the desirability of public intervention in particular areas.

Public sector involvement is often required or encouraged by the failure of markets to provide certain goods and services optimally, or perhaps at all. There is a tendency for economists to think of any discussion of public-infrastructure goods in terms of the generic economic term 'public goods.' The second possibility is thus to interpret public infrastructure in the sense of public, or collective, benefit. These goods and services may be characterized by non-excludability, natural monopoly, externalities or high transactions costs.

It is therefore natural for economists to ask whether infrastructure assets generally are associated with these situations and to use the resulting answer to help define whether particular infrastructure assets fall into the public domain.

4.2.1 Non-excludability, natural monopoly, externalities

For economists, public goods are those from which people cannot be excluded from consuming, and that may or may not be non-rivalrous in consumption. This characteristic leads to market failure and to public provision.

We believe that to define public benefit in this way for public infrastructure would be a mistake. To illustrate the point, imagine that all roads were toll roads, owned and operated by private companies, and road use was monitored by cameras, satellites, sensors in the road, etc., and bills issued. It is now technologically feasible to implement such a system. Such a road system would not be non-excludable. Nevertheless, few would conclude that these roads are not part of public infrastructure.

Economists are also prone to think in terms of government intervention when industries are monopolists—long arguing for types of regulation in these cases. Monopolies arise naturally when they are based on assets possessing such large economies of scale that costs are minimized when one producer supplies the entire market.

Industries that have a heavy concentration of engineering assets have in the past been classified as natural monopolies. Communications, rail transportation and electricity producers have been dominated by single producers in most markets and heavily regulated. And, in each of these cases, the assets have been characterized as subject to large-scale economies—thus producing natural monopolies.

In our previous example, the firm running this hypothetical road system would probably be a natural monopoly because of economies of scale, and if one were inclined to think in terms of market failure more generally (i.e., natural monopolies and externalities) as the characteristic that defines public infrastructure, toll roads would probably be public infrastructure. But another example that is not non-excludable, as evidenced by your latest billing statement, and not a natural monopoly, as evidenced by the number of firms in the industry, are cellular telephone services. Yet, if one considers the public or relatively recently privatized traditional telephone companies' landlines as public infrastructure, one would be tempted to put cellular-telephone transmitters in the same category. A failure of either system of communication would have widespread and serious consequences on the economy.

These examples suggest that non-excludability and other sources of market failure are neither necessary nor sufficient to classify an asset as public infrastructure. It is true that many of the activities that involve public infrastructure do entail some sort of market failure; but we argue that these are a by-product of public infrastructure's other characteristics, rather than a defining characteristic itself.

Neither non-excludability nor externalities necessarily need to lead to public intervention. But these characteristics, along with the key characteristics outlined above, are ones that give rise to special contractual problems that often are associated with state intervention. It is these contractual problems that, we argue, define what should be included in infrastructure assets.

We define infrastructure as a set of assets possessing certain characteristics that give rise to specific economic problems that are pervasive across different economies. This approach has the advantage that it is firmly grounded in economic theory. Economic theory describes the nature of assets that will lead to imperfect market outcomes like monopolies that develop because of the characteristics of the production process that, in turn, are related to the nature of the capital assets that provide the foundation for production in these industries. In addition, the economic theory of contracts can be used to guide us in the choice of the characteristics of assets that create problems for the economic system—that either make for difficult and perhaps imperfect outcomes in the market system (natural monopolies) or that lead to public intervention.

The key characteristics of infrastructure assets that give rise to contractual problems and that exacerbate risk are the long-lived nature of the assets and their immutability. These characteristics give rise to high risks to investors for two reasons. First, the long lives of these assets mean that planning horizons need to take into account events that occur far into the future. Since prediction of future events is difficult, the investment decision in these cases is particular difficult, given our innate imperfections—what Williamson (1975) refers to as our bounded rationality. Second, investors are particularly susceptible to disruptive contractual proceedings (often referred to as hold-up problems) since their assets, once committed, cannot be moved to alternative uses. A shoe manufacturer can move his equipment from one plant to another. A railway is not so easily moved.

While infrastructure assets therefore give rise to well-understood economic problems, it should be recognized that the severity of these problems varies across assets, over time and between countries. The problem that long-lived immutable assets pose is often solved, in various ways, by the private sector without any intervention from the state. Private contracts can be written between suppliers of the service (investors in the engineering assets) and consumers. The operators of pipelines (which are classified as engineering assets) write forms of long-term contracts with producers or with consumers of oil and gas.

But it is also the case that public authorities have often been called upon to facilitate the problem of contract enforcement—for a number of reasons. And this intervention has taken different forms. In some cases, it has involved the granting of long-term protected franchises in return for the right to arbitrate the contract prices with consumers—natural gas regulation or telephones, for example. In other cases, the contract arbitration process became so rancorous that contracts became impossible to write and the state ended up owning the infrastructure.[8]

In some cases, contractual failure between the immediate parties concerned threatened others—forcing the state to intervene to maintain law and order. An example of this can be found in the history of the provision of municipal water services. There are histories of the private ownership of some of these systems that failed when rancorous disagreements about whether a homeowner was covered occurred during a fire-fighting emergency and threatened other nearby home owners.

The issue of excludability discussed earlier also hinges on contract costs. It is admittedly the case that toll roads can be constructed with devices that handle excludability—but the enforcement of those contracts often brings the state into the fray in ways that are quite different from normal contractual relations. For example, the state may be asked to prevent others from competing. There are numerous examples of the state being asked to intervene to use its powers of eminent domain to reduce the costs faced by an entrepreneur collecting land or to prevent others from developing distribution systems, as in the case of the early telephone companies.

The rich history of contractual problems with long-lived immutable assets provides us with an understanding of the complexity of the problems that are associated with engineering assets. But they tell us little about what should be classified as necessarily 'public.' What ends up by being public very much depends on the ability of private parties to solve their contractual problems, whether a country's constitution protects private property from being exploited when the state takes an interest in proceedings (see Baldwin 1989), the emergence of new competition that destroys the natural monopoly, the strength of consumer lobbies that feel exposed to strategic behaviour by those who invest in engineering assets, and many other factors.

These vary across countries and over time. What is at one time a natural monopoly will not remain when new competitors spring up. Land-line telephone companies now face significant competition from wireless companies. What was once a very linear pipeline system leading from the energy-producing provinces that served consumers in only one region now spreads out in many directions, offering producers multiple markets. Electricity is now traded in North American markets once more giving producers many more alternatives than they once had.

This means that deciding whether an infrastructure asset is public or not, in terms of whether excludability or natural monopoly is perceived to be a problem, will leave a statistical agency with a delicate problem of having to decide individually on whether contractual problems are large or small. Statistical agencies are ill-equipped to perform this function.[9] More importantly, if they attempt to define what is public in this sense, they will be seen to lose their objectivity that

8. For examples, see Baldwin (1989).
9. But that will or should not prevent them responding to definitions of what is in the 'public interest' supplied to them by the policy process.

is so crucial for maintaining a reputation for providing unbiased statistical information to the public. Finally, should ‘public’ infrastructure be defined in this way, data on infrastructure that are collected by statistical agencies in different countries will not always be comparable across countries.

4.2.2 A form of externalities: The special nature of networks

The literature on infrastructure invariably makes reference to the need for security in special circumstances. Security in these circumstances is being used to refer to the needs of a country when faced by external threats but also to a particular form of threat to the economy from a disruption of services—where the state has consistently taken the position that it has the authority and the right to intervene.

The state has consistently chosen to regulate contracts *ex ante* when it was appreciated that certain circumstances placed one party under duress. The tired traveller faces considerable duress and often few alternatives. Rates and conditions at inns and hotels are therefore industries that were consistently among the first that the state regulated.

Public authorities have also intervened consistently in industries that produce products that are used extensively by other industries, where the goods cannot be stockpiled as inventory and where disruption offers potentially widespread impacts on the economy. Examples of interventions are concentrated on situations that involve service network*s*—the provision of transportation, electricity and energy systems.

In general, networks serve to support an entity’s expansion over an extensive or intensive area by permitting the transfers of goods and services, factors of production and information between its constituent parts. In this sense, networks form a foundation on which other activities can be built.

Networks are, by their nature, infrastructural. They take time to build, because they are usually not useable until a good portion of them are built. Because of their geographical extensiveness, they tend to involve large initial costs. In addition, once built, the marginal cost of using them is usually low, at least relative to the cost of building them. This characteristic is usually associated with natural monopolies and leads to two-part tariffs—with low marginal costs on one hand and fixed charges on the other hand, so as to cover average costs. These fixed costs are akin to taxes and often are associated with state supervision to ensure that equity considerations are fulfilled when relative prices are set.[10]

They also often have a public character to them. ‘Public’ networks have a large number of users. Thus, any disruption in the network is felt by a large number of people. A disruption in the network thus causes substantial disruption to a large number of people.

10. Regulation in this area has focused on equity across consumers and across regions—urban/rural differences have been among the most important considerations on which the regulatory process has focused.

A list of industries that fall within this boundary would include

i) Transportation and communication
ii) Water and sewage that serves an urbanized population
iii) Electricity and power, which is a universal input.

There is little doubt that the sudden disruption of services on this list would have serious consequences on the health of the economy. It should, however, be noted that this characteristic alone does not warrant inclusion of an activity on our infrastructural list. There are clearly other activities that can have a large impact on the economy. Shutting down all gasoline depots is an effective way of bringing substantial parts of an economy to a standstill—as industrial actions in France have proven. But where infrastructure assets are involved that have the characteristics outlined in a previous section and the output of the industry has the characteristics outlined above, disruptions are so potentially disruptive that many countries have taken particular interest in the state of infrastructure—taking out an option, so to speak, to insure themselves against certain events that the normal functioning of markets is unable to do—because of the imperfections of private contracting in the areas of disasters where the normal tort system recognizes Acts of God.[11]

But it is important here to distinguish between the type of production process (a network) and the asset base (engineering structures) of the process to isolate the origin of the problem, just as it was in the case of externalities and market failure. Is the vulnerability the result of the existence of a network or the nature of the underlying assets? We believe it is the latter. There are few examples of networks in which considerable public interest has been expressed that do not rely on the type of fixed assets that lead to contractual difficulties. It is really the existence of fixed engineering assets that gives rise to problems that lead to state intervention.

4.3 Public benefit

The third way to define the public nature of public infrastructure is to consider its role in the economy and society. In this case, industries can be selected in terms of their function, rather than whether their provision is subject to (as in the public sector classification) or requires or would benefit from (as in the public-goods–market-failure classification) public sector involvement. Defining public infrastructure, according to functional criteria, requires defining the role it plays in the economy and society.

11. As a result, normal insurance contracts cannot be used by private parties to manage risk.

4.3.1 Functions of core infrastructure

From the assets commonly considered as ‘core’ infrastructure, it is possible to discern three functions that they are said to perform for society:

1. Transportation and communication allow for people in geographically distant areas to interact with one another.
2. Transportation, communication, water and sewage allow for the concentration of many people in the same area.
3. Electricity and power is a universal input. All activities use energy in some form or other.

In other words, most of the categories of core infrastructure exist to facilitate relationships among people, either in close quarters or at a distance. Since market economies are defined by these interactions, infrastructure capital is seen to be a facilitator for activities that are central to the economy, and to society.

These arguments for the special treatment of these industries do not rest on very firm foundations. There are many goods that are essential for interactions; there are many goods that are necessary for the operation of cities; there are other inputs that are found in many industries. It is not clear what criteria make these sectors more important in these areas than the goods produced by other industries.

5 Selecting public infrastructure assets and the industries containing them

No matter the industry in which they are found, infrastructure assets have the type of characteristics that lead to special contractual problems. In many cases, the problems are resolved. They may be resolved by the type of arm’s-length contracts referred to earlier in the example of the pipeline industry. Or they may be internalized by having the firm that needs the service of a particular asset invest in that asset—even though it would prefer to contract on an arm’s-length basis. For example, electrical facilities were developed earlier within forest companies and even now can be found in smelting firms like aluminum, thereby internalizing difficult contractual problems within the firm.

In other cases, the nature of the resolution of the problem has involved various types of state intervention—from outright ownership to regulation. The nature of the resolution varies considerably from country to country and industry to industry.

This means that developing a taxonomy for infrastructure that is based on asset characteristics provides greater comparability for cross-country studies than a taxonomy that is based on definitions that attempt to delineate what amounts to an asset meriting the ‘public’ classification—because the latter depends upon other factors than just the characteristic of the asset. It depends on the institutions of the country. These institutions include the nature of tort law for resolving disputes, the political process's interest in facilitating dispute resolution, the protection that is offered to private property and the stage of development of the economy. The latter is particularly important when it comes to the likely impact of a breakdown of the network systems that depend so much on infrastructure capital.

This paper defines infrastructure as a set of fixed structures with the specific characteristics giving rise to contractual problems—that have long useful lives, whose creation involves a considerable gestation period, that have no good substitutes, and that underpin the production of a flow of services for which it is difficult to maintain inventories. These assets also have a special foundational role, supporting other factors of production.

Fortunately, the existing collection systems of Statistics Canada already use a taxonomy that enables us to identify the assets with these characteristics. They fall under the general category that we refer to as fixed structures—consisting of engineering structures and buildings. However, determining which of them have a foundational public interest role is more difficult. Determining which of the structures have qualities that make them public in nature is a task that is not undertaken here. It would require an analysis of why the commercial sector cannot resolve the contractual problems that require public intervention to guarantee adequate supply. Since that is not the task of statisticians and its importance differs jurisdiction by jurisdiction, we forego any attempt to do so herein.

We proceed here in two steps to develop a set of statistics on infrastructure capital. While our primary focus is on delineating the importance of the assets that constitute infrastructure per se, we also group them according to the function that they serve—because of widespread interest in what they do. We focus on classifying those assets that are candidates for public infrastructure (engineering construction, building construction) by their function. The functions are[12]

1. Communications
2. Transportation
3. Energy distribution
4. Electricity
5. Waste, water and sewage
6. Recreation, culture and education
7. Health and social protection
8. Defence and public safety

At the second stage, we develop data by detailed industry groups. By providing data by industry, we allow the analyst to tailor the data to his or her specific purposes—making his or her own decision on the critical public interest that needs to be devoted to that industry, in light of other information on market failure, externalities or the existence of public goods.

In doing so, we start with the traditional industry classification of the public sector—where a substantial proportion of services are provided through public ownership—public administration, health and education. We then group a set of industries that a) have been the subject of

12. We are not considering as infrastructure the assets whose primary purpose is to support agricultural, manufacturing, and mining activities, and services.

regulatory activity and b) contain large amounts of engineering assets that give rise to contractual problems. We choose these core 'infrastructure' industries, not because they are necessarily candidates for regulation today (although they have been in the past), but because the concentration of a particular form of long-lived asset gives rise to particularly difficult contractual problems that may, in turn, affect the adequacy of capital stock in these industries.

The industry classifications that we use correspond to the following 2002 North American Industry Classification System (NAICS) industry codes.

Industry classifications	
Public sector	Public administration (91)
'Regulated' industries	Electric power generation, transmission and distribution (2211)
	Natural gas distribution (2212)
	Water, sewage and other systems (2213)
	Waste management and remediation services (562)
	Transportation (48) (except Pipeline transportation [486])
	Pipeline transportation (486)
	Telecommunications (517)
	Postal service (491)
	Couriers and messengers (492)
	Educational services (61)
	Health care and social assistance (62)
Other sectors	Agriculture, forestry, fishing and hunting (11)
	Mining and oil and gas extraction (21)
	Manufacturing and construction (23, 31-33)
	Wholesale and retail trade, warehousing and storage (41, 44, 493)
	All other industries (real estate, finance, culture and information, entertainment, service sectors)

The industry structure that we have chosen here is based on the standard NAICS. Our industry categories correspond to the following two- (three-, four- where necessary) digit NAICS codes. We group industries into three major groups. The first contains those that are referred to as the public sector, which includes federal, provincial and municipal services, along with non-profit enterprises. The second is referred to as 'regulated' industries. These are industries that involve a mixture of publicly owned and privately owned enterprises, each of which is regulated to differing degrees with respect to the price or the rate of return that can be earned. The rest of the NAICS industries are classified as 'other.' While many industries therein face various forms of regulation (health, safety, labour regulations, licensing regulations), they rarely face the type of public oversight that can be found in the 'regulated' industries.

The inclusion of Couriers and messengers (492) and the entire transportation sector, including Truck transportation (484) in the regulated sector is perhaps anomalous. Neither of these industries would strike one as subject to more government regulation than any of the other industry not included. We include them here because they are close substitutes and/or complements with industries that are likely to be subject to government involvement. Couriers compete with postal services. In the case of trucking services, they are often part of a supply chain that includes planes, boats and trains, or they may compete with these other transportation sectors, which are often regulated. In any case, neither of these industries has much in the way of classifiable infrastructure assets, so including them is unlikely to have a discernable impact on our analysis.

Thus, we will first choose to examine public sector capital and the capital of industries in sectors with substantial public sector involvement, the so-called 'core' infrastructure industries listed above. We will also keep track of infrastructure assets outside of these two sectors—in what we refer to as 'other' industries. We also consider mining separately because it has a large and rising share of total engineering construction. Together, public administration, the 'core' infrastructure sectors, mining and 'other' industries cover the total economy.

6 Infrastructure: Functions supported and industry of location

The following two sections provide data on the value of infrastructure capital in the Canadian economy, where it is found and how it has evolved over time. The first section develops a classification system for infrastructure that groups each type of infrastructure used in the Canadian economy into functional classifications using the characteristics of each type of structure. It then details which industries use those assets most extensively. The subsequent section develops stylized facts about how investments in infrastructure in each category have evolved over time.

In this paper, we consider all engineering and building construction together—what we refer to jointly as 'structures.' Almost all of engineering assets fall into our definition of infrastructure. We believe a smaller proportion of our buildings do so. But in the interests of providing our readers with the underlying statistical information that they need, should they disagree with our choice, we provide data on both categories.

To allow us to better distinguish 'special capital' from other capital assets, we divide structures into functional categories according to their purpose. For asset classes that do not have a single purpose, or for assets of which the purpose is unknown, we put them into a residual category, regardless of the industry in which they are found.

Considering all engineering and building construction assets in various sectors has not only the advantage of not-prejudging whether government intervention is required but also handles practical difficulties in collecting statistics. Systematic evidence on ownership is rarely available, let alone information on regulation or subsidy.

The second criterion sometimes used to define infrastructure (peculiarly critical or complementary assets) is also unhelpful, unless we have a clear specification of the nature of the relationship of infrastructure to other parts of the economy. This task can only be done after a list of assets is provided and researchers can test the complementarities of different assets across the economy.

6.1 Classifying the assets

Of the 98 classes of structures listed in the Canadian economy, there are 62 types of engineering construction and 36 types of buildings. These are the two classes that make up our 'structures' aggregate that we treat as infrastructure here. Of the classes devoted to engineering construction, 57 assets have a single discernable purpose. Of the buildings, 23 types have a clear single purpose. The assets that cannot be identified by function are labelled as 'other.'

The functional classification of assets is straightforward. Engineering and building assets are considered separately. If the asset has a clear single purpose—roads and runways are transportation, electrical power transmission cables are electricity generation and distribution—then it is classified to this function. In the cases where no single function can be discerned, or where the asset may have different functions depending on the industry in which it appears, the assets are classified as 'other.' Although the function of some assets might be clear when matched with an industry, we still include them in 'other.' In doing so, we avoid introducing an element of subjectivity to the classification system.

We stress that the functional classifications relate to the services provided by the **asset** and not to the goods and services provided by the **industry** in which they are recorded. Roads recorded in Electric power generation and distribution are assumed to provide transportation services, not electricity services. One may wish to classify it the other way, by industry output, and not by asset function, so we also consider total fixed capital—engineering construction and building construction as separate categories—for each of the industries listed above. In practice, this will not make a discernable impact: the number of roads in the electricity industry is negligible, both relative to total road capital and to its own engineering capital, and it is the same in other industries and other assets.

The functional categories that we have chosen are listed below and are broadly similar to the Classification of the Functions of Government (COFOG), with minor changes necessitated by asset characteristics. We describe the COFOG classification system and present a more detailed breakdown of the COFOG categories and the assets associated with them in Appendix A. We present just the broad classes and associated assets below.

The match-up between the assets' functional groupings and the industry groupings that were outlined previously can be found in Appendix B.

6.2 Stylized facts of the functional categories

- To which functional purpose are most of the infrastructure assets devoted in the Canadian economy?

The relative importance in the total 'fixed capital stock' of each type of structure in each functional category asset types is presented in Tables 1-1 to 1-4. We add mining; agriculture, manufacturing, and services; and 'other' (non-classifiable) for comparison.

Table 1-1
Distribution of total economy's structures, by functional category — Transportation, communications and electricity

Year	Functional category								
	Transportation			Communications			Electricity		
	E	B	T	E	B	T	E	B	T
	percent								
1970	38.8	1.0	19.2	3.8	1.2	2.4	24.1	0.0	11.6
1980	33.1	1.0	17.1	3.1	1.4	2.2	26.6	0.0	13.3
1990	30.0	0.9	13.7	3.5	1.3	2.3	25.7	0.0	11.3
2002	27.2	1.6	12.7	4.1	1.0	2.3	20.1	0.0	8.7

Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 1-2
Distribution of total economy's structures, by functional category — Waste, water and sewage, and energy distribution; recreation, culture and education

Year	Functional category					
	Waste, water and sewage, and energy distribution			Recreation, culture and education		
	E	B	T	E	B	T
	percent					
1970	16.0	0.0	7.7	0.8	23.1	12.4
1980	15.0	0.0	7.5	0.9	15.8	8.3
1990	17.1	0.0	7.5	0.8	11.7	6.9
2002	17.0	0.0	7.4	0.9	12.5	7.4

Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 1-3
Distribution of total economy's structures, by functional category — Defence and public safety, health and social protection, mining

Year	Functional category								
	Defence and public safety			Health and social protection			Mining		
	E	B	T	E	B	T	E	B	T
	percent								
1970	0.0	1.1	0.6	0.0	6.1	3.2	10.6	0.0	5.1
1980	0.0	1.1	0.6	0.0	5.2	2.6	15.1	0.0	7.6
1990	0.0	0.9	0.5	0.0	5.0	2.8	16.2	0.0	7.1
2002	0.0	1.2	0.7	0.0	5.7	3.2	25.6	0.0	11.1

Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 1-4
Distribution of total economy's structures, by functional category — Agriculture, manufacturing and services; other

Year	Functional category								
	Agriculture, manufacturing and services			Other			Total		
	E	B	T	E	B	T	E	B	T
	percent								
1970	22.3	2.6	12.8	3.3	45.2	25.1	100.0	100.0	100.0
1980	20.6	2.8	11.7	3.3	55.0	29.2	100.0	100.0	100.0
1990	19.9	3.4	12.7	3.3	60.3	35.2	100.0	100.0	100.0
2002	17.6	2.8	11.2	2.3	60.5	35.3	100.0	100.0	100.0

Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Most of the building capital is found in the 'other' category, but that is primarily due to its dominance in building construction (rising from around 45% in 1970, to over 60% in 1990). The next most important sectors are culture and education (consisting mostly of building capital) and health.

Engineering construction is concentrated in transportation—though the importance of engineering construction here has fallen over the years. Transportation possessed over one third of all engineering construction capital in 1970, dropping to about one quarter in 2002. Engineering construction in mining, on the other hand, rose from around 11% in 1970, to close to 26% of the Canadian economy's engineering construction in 2002. The second largest infrastructure sector was electricity, which also declined slightly over time. Waste, water and sewage also accounted for a substantial proportion of engineering construction.

- Which industries contain the most infrastructure assets?

In this section, we turn to examine the distribution of engineering assets across industries—rather than functions—in order to understand whether this alternative classification scheme provides us with a very different picture. Distributions of, say, communications infrastructure across industries would be different from distributions of communications assets across functions if, for example, communication assets were widely distributed across many industries other than the communications industries—if firms outside of communications invested heavily in their own communications systems.

Tables 2-1 to 2-5 show the share of structural assets across industries. Engineering construction is concentrated in two industry sectors—public administration and electrical utilities. Engineering capital in those two sectors adds up to over 50% of the total. Together with telecommunications and transportation, over 65% of engineering construction assets was in the public sector or the 'regulated' industries in 2002.

Table 2-1
Shares of total economy's structures, all functions, by industry — Public administration and transportation

Year	Industry					
	Public administration			Transportation[1]		
	E	B	T	E	B	T
	percent					
1970	32.2	32.7	32.5	9.7	1.4	5.4
1980	29.4	24.2	26.8	6.6	1.4	4.0
1990	27.9	19.2	23.0	6.2	1.3	3.4
2002	25.8	21.4	23.3	5.7	2.0	3.6

1. Includes industries under Transportation (48) from the North American Industry Classification System, except Pipeline transportation (486).
Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 2-2
Shares of total economy's structures, all functions, by industry — Communications and electricity

Year	Industry					
	Communications[1]			Electricity[2]		
	E	B	T	E	B	T
	percent					
1970	3.6	1.1	2.3	24.1	0.5	11.8
1980	3.1	1.4	2.2	26.8	0.7	13.7
1990	3.4	1.3	2.2	25.9	0.7	11.8
2002	4.0	1.2	2.4	20.4	0.9	9.4

1. Includes Telecommunications (517), Postal service (491), and Couriers and messengers (492) industries from the North American Industry Classification System (NAICS).
2. Includes Electric power generation, transmission and distribution (2211) industries from the NAICS.
Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 2-3
Shares of total economy's structures, all functions, by industry — Waste, water and sewage, and energy distribution; agriculture

Year	Industry					
	Waste, water and sewage, and energy distribution[1]			Agriculture[2]		
	E	B	T	E	B	T
	Percent					
1970	8.9	0.2	4.4	4.3	3.9	4.1
1980	8.4	0.1	4.3	3.6	3.4	3.5
1990	10.0	0.1	4.5	3.5	2.5	2.9
2002	10.6	0.3	4.8	2.5	2.4	2.5

1. Includes Natural gas distribution (2212); Water, sewage and other systems (2213); and Waste management and remediation services (562) industries from the North American Industry Classification System (NAICS).
2. Includes Agriculture, forestry, fishing and hunting (11) industries from the NAICS.
Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 2-4
Shares of total economy's structures, all functions, by industry — Mining and other

Year	Industry					
	Mining[1]			Other[2]		
	E	B	T	E	B	T
	percent					
1970	13.3	2.6	7.7	3.8	57.6	31.8
1980	18.2	2.2	10.2	3.9	66.5	35.2
1990	20.1	1.6	9.8	3.1	73.4	42.4
2002	28.6	1.3	13.1	2.4	70.5	41.0

1. Includes Mining and oil and gas extraction (21) industries from the North American Industry Classification System (NAICS).
2. Includes Manufacturing and construction (23, 31-33); Wholesale and retail trade, warehousing and storage (41, 44, 493); and all other industries (real estate, finance, culture and information, entertainment, service sectors) from the NAICS.
Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 2-5
Shares of total economy's structures, all functions, by industry — All industries

Year	Industry		
	All industries		
	E	B	T
	percent		
1970	100.0	100.0	100.0
1980	100.0	100.0	100.0
1990	100.0	100.0	100.0
2002	100.0	100.0	100.0

Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Engineering construction shares have stayed relatively constant for most of the categories over the sample period, with the exception of mining, which rose from 13% to 29% of non-mining engineering construction, and transportation, which dropped from 10% to 6%. The drop in the transportation industry was mostly attributable to a decline in the relative importance of rail capital.

- How important are engineering assets within specific industries?

While the distribution across industries tells us where most of the engineering capital is located, the distribution of capital, by type, within each industry (Table 3) reveals whether engineering construction is also important in that sector or whether other types of capital dominate infrastructure capital.

The data in Table 3 reveal that the 'regulated' industries focus primarily on engineering construction since they tend not to use many buildings. Public administration uses engineering construction and buildings in roughly equal proportions. The other industries, with the exception of mining, use more buildings than engineering construction.

Table 3
Share of capital, by type, of industry's total capital

	Engineering construction	Building construction	Machinery and equipment
	percent		
Public administration			
1970	44.7	49.2	6.1
1980	51.6	42.5	5.9
1990	48.0	41.9	10.0
2002	42.3	46.0	11.7
Transportation			
1970	53.8	8.2	38.0
1980	47.6	10.0	42.4
1990	43.3	11.3	45.4
2002	29.2	13.6	57.2
Communications			
1970	36.1	12.5	51.3
1980	33.9	15.6	50.5
1990	35.0	16.7	48.3
2002	34.0	13.2	52.8
Electricity			
1970	77.0	1.6	21.4
1980	72.3	1.8	25.9
1990	70.0	2.3	27.7
2002	69.3	4.0	26.8
Waste, water and sewage, and energy distribution			
1970	91.7	2.1	6.2
1980	92.4	1.5	6.1
1990	91.6	1.3	7.1
2002	87.7	3.4	8.9
Agriculture			
1970	24.0	23.3	52.7
1980	21.5	20.3	58.2
1990	29.9	27.2	42.9
2002	24.5	31.3	44.2
Mining			
1970	68.1	14.6	17.3
1980	74.6	9.2	16.2
1990	80.4	8.1	11.5
2002	79.6	4.8	15.6
Economy average			
1970	36.3	39.4	24.3
1980	37.3	37.3	25.3
1990	32.7	41.4	25.9
2002	30.3	39.8	29.9

Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Both the amount of engineering construction in the regulated industries and the relatively low proportion of buildings in their total capital stock suggest that these industries should be the primary focus of any discussion about engineering infrastructure outside the public sector.

- *Within functional groups, how important are assets of different industries?*

In assessing the importance of the adequacy or the size of assets that are available to support a particular function (communications or transportation), it is important to know the extent to which assets serving a particular function are found in the North American Industry Classification System (NAICS) industry with the corresponding title or whether they can be found across many sectors. A particular function like communications may have most of its assets provided by different industries or only in what the NAICS calls the communications industry.

Tables 4-1a to 4-7b detail the distribution of engineering and total fixed capital (TFC=engineering + building construction, where the latter exists) assets within the functional categories, across industries.

Table 4-1a
Industry's share of total economy's structures, by functional category — Transportation capital type – Public administration; transportation; waste, water and sewage, and energy distribution

	Industry								
	Public administration			Transportation			Waste, water and sewage, and energy distribution		
	E	B	T	E	B	T	E	B	T
Year	Percent								
1970	60.2	23.2	59.2	24.9	74.1	29.3	1.0	n.r.	1.0
1980	64.8	20.9	63.5	19.9	76.7	23.9	1.9	n.r.	1.8
1990	64.7	19.9	63.1	20.4	78.2	25.4	1.2	n.r.	1.1
2002	67.2	9.3	63.0	20.9	88.4	28.3	0.6	n.r.	0.5

n.r. asset type not recorded for that industry
Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 4-1b
Industry's share of total economy's structures, by functional category — Transportation capital type – Electricity, mining and other

	Industry								
	Electricity			Mining			Other		
	E	B	T	E	B	T	E	B	T
Year	percent								
1970	0.1	n.r.	0.1	0.9	n.r.	0.8	1.7	2.7	1.7
1980	0.0	n.r.	0.0	0.7	n.r.	0.7	1.8	2.5	1.8
1990	0.0	n.r.	0.0	0.8	n.r.	0.7	1.3	2.0	1.3
2002	0.2	n.r.	0.1	0.5	n.r.	0.4	1.5	2.4	1.6

n.r. asset type not recorded for that industry
Notes: E=Engineering Construction; B=Building Construction; T=Total Construction Capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 4-1c
Industry's share of total economy's structures, by functional category — Transportation capital type – Agriculture

	Industry					
	Agriculture			Total		
	E	B	T	E	B	T
Year	Percent					
1970	11.1	n.r.	10.8	100.0	100.0	100.0
1980	10.9	n.r.	10.6	100.0	100.0	100.0
1990	11.6	n.r.	11.2	100.0	100.0	100.0
2002	9.2	n.r.	8.6	100.0	100.0	100.0

n.r. asset type not recorded for that industry
Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 4-2a
Industry's share of total economy's structures, by functional category — Communications capital type – Public administration, communications and transportation

	Industry								
	Public administration			Communications			Transportation		
	E	B	T	E	B	T	E	B	T
Year	Percent								
1970	3.9	31.1	10.9	94.8	56.3	85.0	0.8	n.r.	0.6
1980	1.5	22.9	7.9	97.7	59.0	86.0	0.6	n.r.	0.4
1990	2.4	18.9	7.7	96.9	57.4	84.0	0.7	n.r.	0.5
2002	0.8	16.1	4.5	97.5	56.9	87.7	0.7	n.r.	0.6

n.r. asset type not recorded for that industry
Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 4-2b
Industry's share of total economy's structures, by functional category — Communications capital type – Other

	Industry					
	Other			Total		
	E	B	T	E	B	T
Year	Percent					
1970	0.4	12.6	3.5	100.0	100.0	100.0
1980	0.1	18.1	5.6	100.0	100.0	100.0
1990	0.1	23.7	7.8	100.0	100.0	100.0
2002	1.0	26.9	7.3	100.0	100.0	100.0

Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 4-3
Industry's share of total economy's structures, by functional category — Recreation, culture and education capital type – Public administration and other

	Industry								
	Public administration			Other			Total		
	E	B	T	E	B	T	E	B	T
Year	percent								
1970	100.0	88.2	88.6	0.0	11.8	11.4	100.0	100.0	100.0
1980	100.0	84.4	85.2	0.0	15.6	14.8	100.0	100.0	100.0
1990	100.0	78.3	79.5	0.0	21.7	20.5	100.0	100.0	100.0
2002	90.7	81.4	81.9	9.3	18.6	18.1	100.0	100.0	100.0

Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 4-4
Industry's share of total economy's structures, by functional category — Health and social protection capital type – Public administration and other

	Industry								
	Public administration			Other			Total		
	E	B	Total	E	B	T	E	B	T
Year	percent								
1970	n.r.	99.3	99.3	n.r.	0.7	0.7	100.0	100.0	100.0
1980	n.r.	98.8	98.8	n.r.	1.2	1.2	100.0	100.0	100.0
1990	n.r.	98.5	98.5	n.r.	1.5	1.5	100.0	100.0	100.0
2002	n.r.	95.0	95.0	n.r.	5.0	5.0	100.0	100.0	100.0

n.r. Asset type not recorded for that industry
Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 4-5
Industry's share of total economy's structures, by functional category — Defence and public safety capital type – Public administration and other

	Industry								
	Public administration			Other			Total		
	E	B	T	E	B	T	E	B	T
Year	percent								
1970	n.r.	97.7	97.7	n.r.	2.3	2.3	100.0	100.0	100.0
1980	n.r.	96.2	96.2	n.r.	3.8	3.8	100.0	100.0	100.0
1990	n.r.	97.6	97.6	n.r.	2.4	2.4	100.0	100.0	100.0
2002	n.r.	93.0	93.0	n.r.	7.0	7.0	100.0	100.0	100.0

n.r. Asset type not recorded for that industry
Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 4-6a
Industry's share of total economy's structures, by functional category — Waste, water and sewage, and energy distribution capital type – Public administration; waste, water and sewage, and energy distribution; electricity

	Industry								
	Public administration			Waste, water and sewage, and energy distribution			Electricity		
	E	B	T	E	B	T	E	B	T
Year	percent								
1970	41.4	n.r.	41.4	51.7	n.r.	51.7	0.2	n.r.	0.2
1980	40.6	n.r.	40.6	50.6	n.r.	50.6	0.2	n.r.	0.2
1990	39.0	n.r.	39.0	55.4	n.r.	55.4	0.2	n.r.	0.2
2002	35.7	n.r.	35.7	60.0	n.r.	60.0	0.7	n.r.	0.7

n.r. Asset type not recorded for that industry
Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 4-6b
Industry's share of total economy's structures, by functional category — Waste, water and sewage, and energy distribution capital type – Mining

	Industry		
	Mining		
	E	B	T
Year	percent		
1970	1.3	n.r.	1.3
1980	1.5	n.r.	1.5
1990	1.5	n.r.	1.5
2002	0.8	n.r.	0.8

n.r. Asset type not recorded for that industry
Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division..

Table 4-6c
Industry's share of total economy's structures, by functional category — Waste, water and sewage, and energy distribution capital type – Other

	Industry					
	Other			Total		
	E	B	T	E	B	T
Year	percent					
1970	5.4	n.r.	5.4	100.0	100.0	100.0
1980	7.1	n.r.	7.1	100.0	100.0	100.0
1990	3.9	n.r.	3.9	100.0	100.0	100.0
2002	2.7	n.r.	2.7	100.0	100.0	100.0

n.r. Asset type not recorded for that industry
Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division

Table 4-7a
Industry's share of total economy's structures, by functional category — Electricity capital type – Public administration, electricity and mining

Year	Industry								
	Public administration			Electricity			Mining		
	E	B	T	E	B	T	E	B	T
	percent								
1970	1.3	n.r.	1.3	97.2	n.r.	97.2	1.0	n.r.	1.0
1980	0.5	n.r.	0.5	98.7	n.r.	98.7	0.5	n.r.	0.5
1990	0.5	n.r.	0.5	98.8	n.r.	98.8	0.6	n.r.	0.6
2002	0.3	n.r.	0.3	99.1	n.r.	99.1	0.4	n.r.	0.4

n.r. Asset type not recorded for that industry
Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 4-7b
Industry's share of total economy's structures, by functional category — Electricity capital type – Other

Year	Industry					
	Other			Total		
	E	B	T	E	B	T
	percent					
1970	0.4	n.r.	0.4	100.0	n.r.	100.0
1980	0.2	n.r.	0.2	100.0	n.r.	100.0
1990	0.2	n.r.	0.2	100.0	n.r.	100.0
2002	0.2	n.r.	0.2	100.0	n.r.	100.0

n.r. Asset type not recorded for that industry
Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Of the first group of infrastructure assets (engineering construction), most functional categories are dominated by public administration and one other 'regulated' sector.

For communications assets, over 90% of the total fixed communications capital and a higher percentage of the engineering capital are in the public administration or telecommunications sector, although public administration plays only a minor role here.

Public administration plays the dominant role in the transportation sector, with 67% of engineering transportation assets. Another 20% is in the transportation sector.

Energy and electricity assets are found almost exclusively in the natural gas distribution, pipeline transportation and the electrical power generation and distribution sectors.

For waste, water and sewage, 35% of the capital is found in public administration, and 60% is recorded under the water, sewage and waste remediation industries.

Of the second category of fixed assets considered here (buildings), the recreation, culture and education; health and social protection; and public administration sectors are dominated by the public administration sector. These assets consist mostly of buildings. Outdoor recreational facilities, found in education and culture, are the only assets classified as engineering construction.

- To what extent are assets within an industry specific to the output of the industry?

Our analysis of infrastructure capital has proceeded by identifying specific assets that fall into this category and then by asking which functions they serve and in which industries they are found. Asking whether functions and industries overlap allows us to decide the purposes to which these assets are put and the industries that support these functions. Asking how important these assets are within an industry allows us to ascertain whether these assets are 'critical' or only supportive in the industries concerned. It is also useful to know whether the assets are somehow directly associated with the production process or whether they are ancillary—since the former are more likely to be critical components and the latter may be less so. For example, an electrical substation is part of the electrical grid. A head office plays a different role. Both are required by the firm; but the former involves more sunk costs than the latter since there are secondary markets for commercial buildings.

Tables 5-1a to 5-4b detail the share of assets in the 'regulated' sectors for which the function of the asset is directly and unambiguously related to the output of the industry (e.g., how much of the building construction in the telecommunications industry is communications buildings and how much is office or other types of buildings). For example, Table 5-1a indicates that, in 1970, 95.3% of the electricity industry's capital is clearly devoted to electricity production and distribution, while 0.2% was aimed at transportation and 4.4% could not be classified according to function.

Table 5-1a
Share of structures with particular functions — Electricity industry's total structural capital, by capital type – Electricity, other and transportation

	Capital type								
	Electricity			Other			Transportation		
	E	B	T	E	B	T	E	B	T
Year	percent								
1970	97.2	0.0	95.3	2.4	100.0	4.4	0.2	0.0	0.2
1980	98.2	0.0	95.7	1.7	100.0	4.1	0.1	0.0	0.1
1990	97.9	0.0	94.8	2.0	100.0	5.1	0.0	0.0	0.0
2002	97.3	0.0	92.2	1.9	100.0	7.2	0.2	0.0	0.2

Notes: E=Engineering construction; B=Building construction; T=Total construction capital. Rows add to 100. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 5-1b
Share of structures with particular functions — Electricity industry's total structural capital, by capital type – Waste, water and sewage, and energy distribution

	Capital type					
	Waste, water and sewage, and energy distribution			Total		
	E	B	T	E	B	T
Year	percent					
1970	0.1	0.0	0.1	100.0	100.0	100.0
1980	0.1	0.0	0.1	100.0	100.0	100.0
1990	0.1	0.0	0.1	100.0	100.0	100.0
2002	0.6	0.0	0.5	100.0	100.0	100.0

Notes: E=Engineering construction; B=Building construction; T=Total construction capital. Rows add to 100. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 5-2
Share of structures with particular functions — Waste, water and sewage, energy distribution industry's total structural capital, by capital type – Waste, water and sewage, and energy distribution; other; transportation

	Capital Type											
	Waste, water and sewage, and energy distribution			Other			Transportation			Total		
	E	B	T	E	B	T	E	B	T	E	B	T
Year	Percent											
1970	93.1	0.0	91.0	0.1	100.0	2.3	4.6	0.0	4.4	100.0	100.0	100.0
1980	90.3	0.0	88.8	0.0	100.0	2.4	7.3	0.0	7.2	100.0	100.0	100.0
1990	94.6	0.0	93.3	0.1	100.0	1.9	3.5	0.0	3.5	100.0	100.0	100.0
2002	96.5	0.0	92.9	0.0	100.0	2.1	1.4	0.0	1.4	100.0	100.0	100.0

Notes: E=Engineering construction; B=Building construction; T=Total construction capital. Rows add to 100. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 5-3
Share of structures with particular functions — Transportation industry's total structural capital, by capital type – Transportation, other and communications

	Capital type											
	Transportation			Other			Communications			Total		
	E	B	T	E	B	T	E	B	T	E	B	T
Year	percent											
1970	99.3	54.0	93.3	0.4	46.0	6.4	0.3	0.0	0.3	100.0	100.0	100.0
1980	99.4	54.5	91.6	0.3	45.5	8.2	0.3	0.0	0.2	100.0	100.0	100.0
1990	99.3	54.5	90.0	0.3	45.5	9.6	0.4	0.0	0.3	100.0	100.0	100.0
2002	99.1	69.8	89.8	0.4	30.2	9.9	0.5	0.0	0.4	100.0	100.0	100.0

Notes: E=Engineering construction; B=Building construction; T=Total construction capital. Rows add to 100. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 5-4a
Share of structures with particular functions — Communications industry's total structural capital, by capital type – Communications and other

Year	Capital type					
	Communications			Other		
	E	B	T	E	B	T
	percent					
1970	100.0	58.4	89.3	0.0	41.6	10.7
1980	99.9	56.8	86.3	0.0	43.2	13.6
1990	100.0	59.9	87.0	0.0	40.1	13.0
2002	100.0	48.0	85.4	0.0	52.0	14.6

Notes: E=Engineering construction; B=Building construction; T=Total construction capital. Rows add to 100. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 5-4b
Share of structures with particular functions — Communications industry's total structural capital, by capital type – Transportation

Year	Capital type					
	Transportation			Total		
	E	B	T	E	B	T
	percent					
1970	0.0	0.0	0.0	100.0	100.0	100.0
1980	0.1	0.0	0.1	100.0	100.0	100.0
1990	0.0	0.0	0.0	100.0	100.0	100.0
2002	0.0	0.0	0.0	100.0	100.0	100.0

Notes: E=Engineering construction; B=Building construction; T=Total construction capital. Rows add to 100. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

In the major regulated industries, over 90% of their engineering construction and total fixed capital consist of assets with a clear function that directly corresponds to the services produced by their industries. With respect to buildings, only a little more than one half of the building assets in the telecommunications sector, two thirds (four fifths in 2003) in the transportation sector, and none in the 'other' industries have the same function as the industry. On the other hand, these industries have relatively little building capital, so total fixed capital is dominated by engineering construction and focusing on the latter is therefore more than adequate for understanding the amount of capital therein that would be classified as infrastructure.

Our analysis in this section reaches the following conclusions. First, with respect to engineering construction, it matters little if we classify assets according to the industry in which they are found or by the nature of the asset. Both lead to roughly similar lists of assets and values of the capital stock. The same cannot be said of building capital, because too few building types can be assigned a single, specific function and many of the buildings appear in multiple industries.

- What is the breakdown by function of public administration assets?

Tables 6-1 to 6-3 perform the same exercise for public sector assets. The breakdown of the public sector's structural capital by function reveals that some 70% to 80% of the public sector's building assets are recorded in culture, education and health. These are primarily schools and hospitals. About 70% and 24% of the public sector's engineering assets are found in the transportation and waste, water and sewage sectors, respectively. In other words, discussions of public sector infrastructure are essentially about schools, hospitals, roads and water mains.

Table 6-1
Share of structures with particular functions of public administration's total structural capital — Communications; recreation, culture and education; electricity

	Communications			Recreation, culture and education			Electricity		
	E	B	T	E	B	T	E	B	T
Year	percent								
1970	0.5	1.1	0.8	2.5	62.3	33.8	1.0	0.0	0.5
1980	0.2	1.3	0.7	2.9	55.0	26.5	0.5	0.0	0.3
1990	0.3	1.3	0.8	3.0	47.7	23.8	0.4	0.0	0.2
2002	0.1	0.8	0.4	3.1	47.5	26.2	0.2	0.0	0.1

Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 6-2
Share of structures with particular functions of public administration's total structural capital — Health and social protection, other, and defence and public safety

	Health and social protection			Other			Defence and public safety		
	E	B	T	E	B	T	E	B	T
Year	percent								
1970	0.0	18.7	9.8	2.9	13.8	8.6	0.0	3.4	1.8
1980	0.0	21.1	9.6	2.6	17.3	9.3	0.0	4.4	2.0
1990	0.0	25.6	11.9	2.6	19.7	10.6	0.0	4.8	2.2
2002	0.0	25.2	13.1	2.2	20.7	11.8	0.0	5.2	2.7

Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Table 6-3
Share of structures with particular functions of public administration's total structural capital — Transportation; Waste, water and sewage and energy distribution

	Transportation			Waste, water and sewage and energy distribution			Total		
	E	B	T	E	B	T	E	B	T
Year	percent								
1970	72.6	0.7	34.9	20.6	0.0	9.8	100.0	100.0	100.0
1980	73.0	0.9	40.4	20.8	0.0	11.4	100.0	100.0	100.0
1990	69.8	0.9	37.7	23.9	0.0	12.7	100.0	100.0	100.0
2002	70.8	0.7	34.3	23.6	0.0	11.3	100.0	100.0	100.0

Notes: E=Engineering construction; B=Building construction; T=Total construction capital. The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

6.3 Summary

1. The special large investments that involve major sunk costs that are called infrastructure here can be found across a number of industries—both public administration and a core set of commercial industries such as utilities, transportation, communications and water.

2. These assets serve several functions—culture and education, health, safety, communications, energy, transportation, waste water and sewage, production of goods and services and several other categories. Taken as a whole, they are devoted primarily to transportation, electricity, culture and education, and water. The capital in buildings is spread much more equally across these functions than is the special investment in engineering construction, which is often seen to be at the core of infrastructure investment. Engineering construction is primarily devoted to transportation, electricity and waste-water management.

3. Infrastructure investment in the public sector is primarily about schools, hospitals, roads and water mains. In the public administration sector, assets are spread about equally between engineering construction and buildings.

4. Infrastructure investment outside the public administration sector in terms of engineering structures has traditionally been found in electrical utilities, transportation and communications. More recently, the share in oil and gas exploration has increased dramatically. In the traditional regulated sector, engineering construction accounts for a large portion of assets—some 74% in electrical utilities, 33% for transportation, 38% for telecommunications. In mining, it accounts for 82% of all assets.

5. The non-mining, oil and gas refining and manufacturing assets that are not in public administration appear overwhelmingly in the sector one would expect them to: non-public administration transportation assets are mostly in the transportation services sector, utilities assets in the utilities sector, etc. Furthermore, the structures in these sectors are overwhelmingly dominated by those assets. For example, around 95% of the assets in the electric power generation and distribution industry are assets that have the singular purpose of generating or distributing electricity. The tight correspondence between certain types of capital and particular industries suggests that alternative ways of classifying infrastructure (i.e., by the nature of the goods and services they are used to produce, rather than by the nature of the asset) will generate similar answers.

6. While the classification of engineering assets is relatively easy, this is not the case for buildings. These assets are less industry-specific and less function-specific. And they may be more easily transferred across both industries and functions than are engineering assets. Buildings are a particular issue for the non-business sector (especially public administration). Most public administration buildings are either schools or hospitals (although there is a large and increasing share of ‘other,’ mainly office buildings).

7 The evolution of infrastructure in Canada (1961 to 2003)

Infrastructure is regarded as having a pivotal role in the economy. And discussions about infrastructure often revolve around whether an economy has an adequate amount of it.

Although infrastructure capital is considered to be singularly important, it is just one of the inputs to the production process. It must be combined with other types of capital and with labour to produce goods and services. The optimal amount of infrastructure will thus be related to the goods and services produced, to the use of these other inputs and to the technology used to combine them. It is therefore natural to ask how this type of capital has changed over the last 40 years, both in relation to the economy's output and to the way in which it is produced.

To do so, we use three measures: the ratio of infrastructure capital to aggregate gross domestic product (GDP), the ratio of infrastructure capital to labour input and the ratio of capital to the population. As we noted earlier, we define infrastructure capital as all structures—both engineering construction and buildings. In each case, infrastructure capital is compared with other measures of capital—so as to assess whether the role of capital has changed or whether the relative importance of the assets that we have defined here as 'infrastructure' have changed in a different way than other forms of assets. We also ask whether the trends are different in the non-commercial sector than in the business sector. This allows us to determine whether there is something unusual about the government sector's changing use of infrastructure.

7.1 Capital-to-GDP ratios

In the first case, we ask whether output has increased as fast or faster than the infrastructure capital that supports that output. Capital is used to transform other inputs (labour and intermediate inputs) into output. The amount of capital that a society uses for this purpose depends upon the savings rate of a society, the type of assets that are bought and the nature of the industrial structure of the economy (whether its industries require large amounts of capital), the productivity of capital and nature of substitution that is taking place between assets as relative prices and technology change.

Economic growth models can be found that produce a stylized world in which there is a constant capital-to-output ratio along a steady state growth path (Solow 1970). [13]

But individual assets within the aggregate capital stock (like infrastructure) may follow different paths for several reasons.

First, increases in the ratio of GDP to infrastructure may occur as a result of the more efficient use of infrastructure capital. Firms can expect to improve their efficiency of all inputs over time. And in this respect, infrastructure capital may be no different from other inputs like labour. The economy increases its living standards by making more with less. Output can also increase relative to infrastructure capital if this type of capital has to be built ahead of demand. Large

13. Solow (1970, 4) defines a steady state when the "output, employment, and capital stock grow exponentially, and its capital/output ratio is constant."

investments in hydro-electric facilities may be made in advance of demand. In this case, output will increase relatively faster than infrastructure capital after the initial investments have been made—as demand expands to fill in new capacity. In this case, capital is being used more intensely over time.

Second, output can also increase relative to infrastructure capital if firms slowly substitute other inputs for infrastructure. The price of computers and computer-related equipment has fallen dramatically compared with the price of infrastructure capital over the last 20 years. Firms may therefore have increased the amount of high-tech machinery and equipment that they use relative to infrastructure capital. Or firms may have chosen to use relatively more high-knowledge employees to increase production rather than 'old-fashioned' infrastructure.

Third, output can increase relative to capital when capital is being overextended, when it is being worked beyond its capacity. Worry is sometimes expressed that infrastructure is being run down unduly, that roads are not being renewed sufficiently, that our water systems have been allowed to deteriorate.

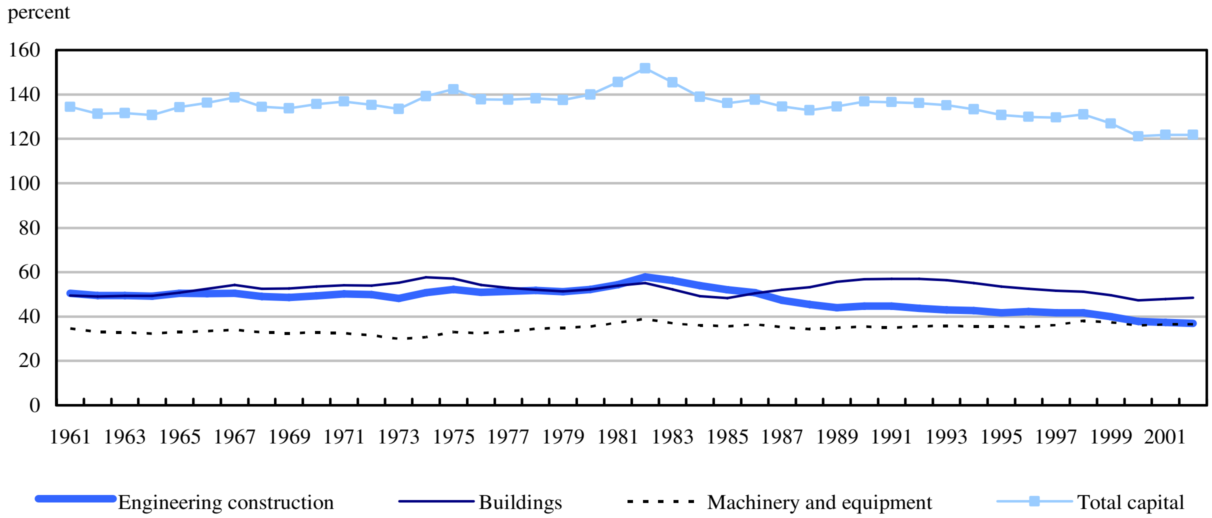
Under the first interpretation, the increase in output per unit of fixed capital (or, conversely, a drop in capital as a fraction of GDP) is a positive thing. It means that these sectors are becoming more efficient. The second interpretation is essentially neutral. These sectors are getting more output in spite of their reduction in infrastructure capital, because they are substituting in other factors of production. The third interpretation is negative: although these sectors are getting more now from their capital, they are also wearing it out faster; their output will drop when their capital wears out.

We start by examining the overall trend in capital, which consists of assets invested in machinery and equipment, buildings and engineering construction. In Figure 1, the amount of net capital in the entire Canadian economy (measured in replacement dollars) divided by current dollar GDP is plotted from 1961 to 2003.[14] Except for the recession years in the early 1980s, this ratio has been relatively constant up until the mid-1990s, but has declined slightly since then. Indeed, the relative constancy of this ratio is suggestive of one of the simple long-run steady state equilibria to be found in the economics growth literature (Solow 1970).

Capital takes on different forms—machinery and equipment, buildings and engineering construction. And these types may substitute for one another as relative prices change. The capital-to-GDP ratios are also plotted in Figure 1 for each of these assets. Machinery and equipment assets, whose relative price has fallen as a result of the information and communication technology revolution, have seen their ratio gradually increase. Buildings have fluctuated around a relatively constant mean—though there has been a long-term decline since the building boom of the late 1980s. Engineering construction expenditures, in contrast to the other two categories, have been in decline relative to GDP since the early 1980s.

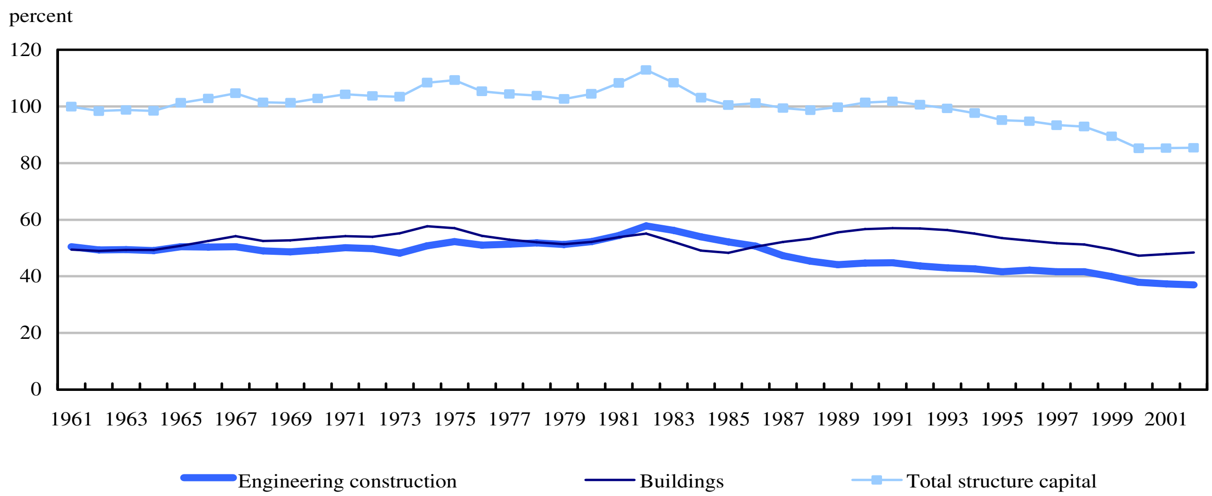
14. For our analysis, when we compare capital and gross domestic product in a particular year, we use the current prices of that year (as is traditionally done in national accounting circles) and not those of other years, since only the prices of that year are relevant for that year. But if we had chosen to create ratios of quantities using constant dollar prices (that is, prices of some other year) the general conclusions reported here would still hold.

Figure 1
Total capital, as percent of gross domestic product, in current prices



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Figure 2
Total structure capital, as percent of gross domestic product, in current prices

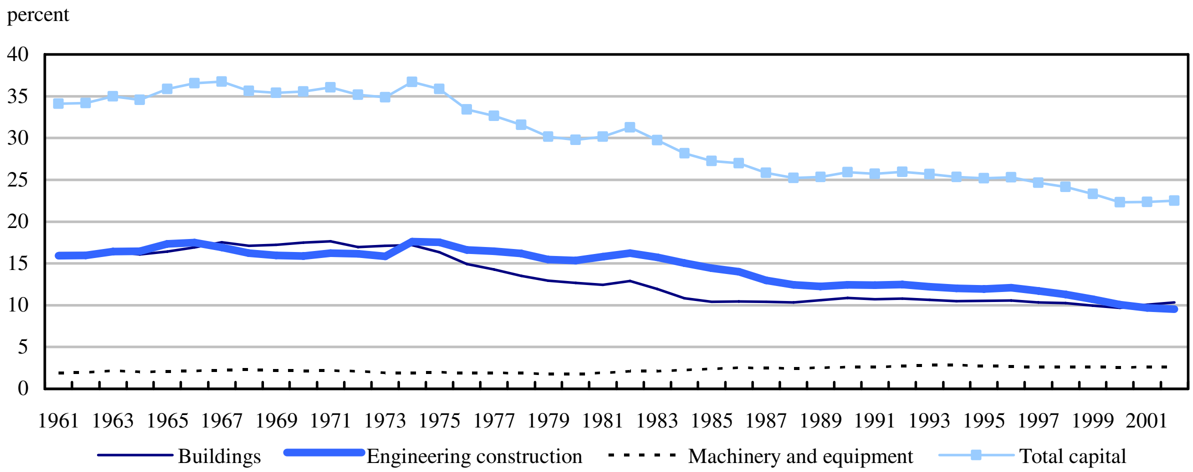


Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

There has also been a drop in infrastructure capital (defined as engineering construction and buildings) as a share of GDP (Figure 2). After fluctuating between 80% and 90% of GDP from 1961 to the early 1990s, this ratio dropped to below 70% after 2000. This fall was almost exclusively due to a drop in the importance of engineering construction, from over 40% of GDP in the 1970s, to under 30% by the end of the millennium.

Of equal interest is the course of public sector capital. The ratio of capital located in the public administration sector to total GDP has fallen dramatically, from over 35% in the 1970s, to less than 25% in 2002 (Figure 3). The fall was due in equal parts to declines in engineering construction and building construction. It should be noted that the change in the publicly owned building construction may partly be due to the government renting buildings rather than owning them, as the drop on the public administration's side has been met with a concomitant rise in the real estate, rental and financial sectors.

Figure 3
Public administration capital, as percent of gross domestic product, in current prices



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

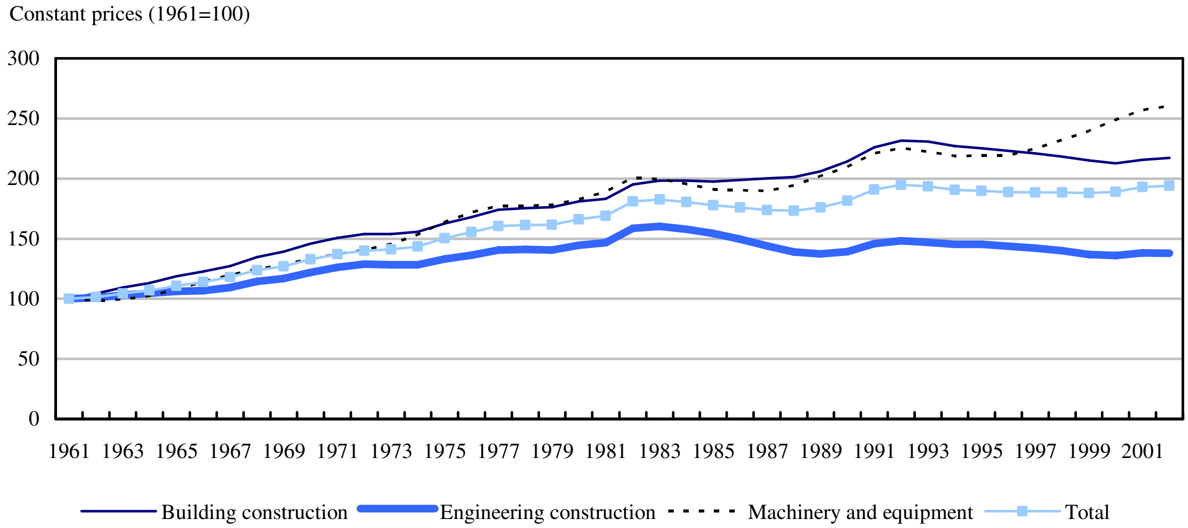
The trends suggest that there has been a drop in the importance of the engineering capital portion of infrastructure capital as a share of GDP, but that these patterns are shared by engineering construction in several sectors of the economy. Thus, whatever forces are driving the capital stock, it is not limited to public sector capital, but they affect the other sectors containing infrastructure as well.

The growth in capital relative to labour

Increasing the amount of capital that is available to workers often enhances labour productivity. Since infrastructure is a part of the capital stock, it is useful to ask what has happened to capital–labour ratios for capital in general and for the various components of capital over time. Therefore, Figures 4, 5 and 6 plot the growth of the stock of all types of capital per hour worked, for the entire economy, and for the mining and non-mining sectors separately.

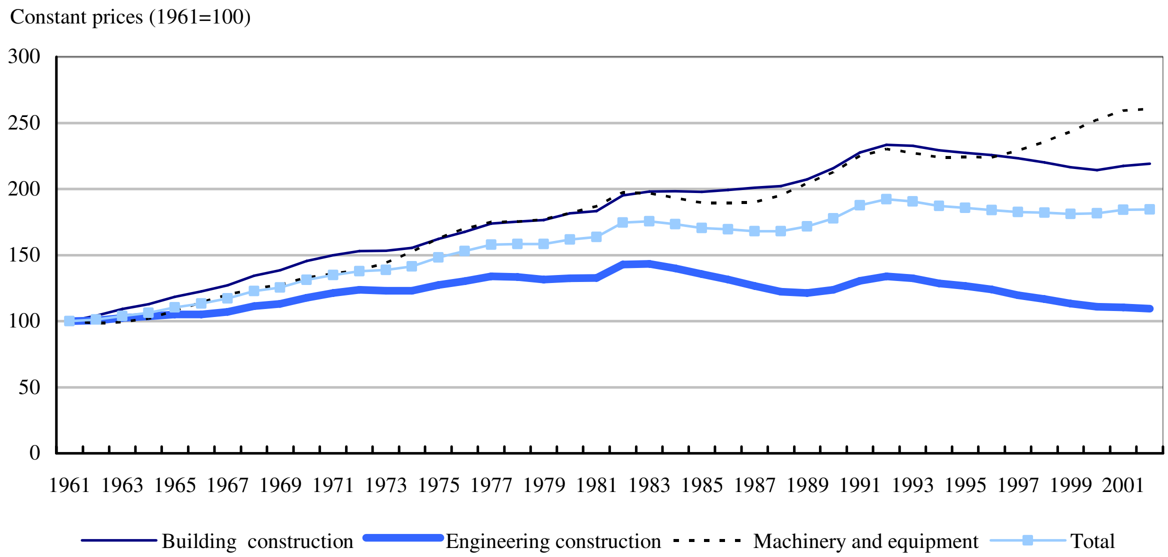
Capital–labour ratios increased for all forms of capital up until 1981. Machinery and equipment and building construction capital per hour worked continued to increase thereafter; this was not the case for engineering construction, which declined slightly after 1981. The trends for engineering construction are even starker when the mining and the non-mining sectors are considered separately. Engineering construction capital per hour worked fell by almost 40% from 1981 to 2002 in the non-mining sector. This fall was offset by a rise of over 100% in engineering construction per hour worked in the mining sector over the same period. The trend then in infrastructure in the commercial sector varies considerably between the traditionally regulated sectors like transportation, electricity, communications and water from the exploration and extraction sectors of the natural resource economy.

Figure 4
Capital per hours worked, total economy



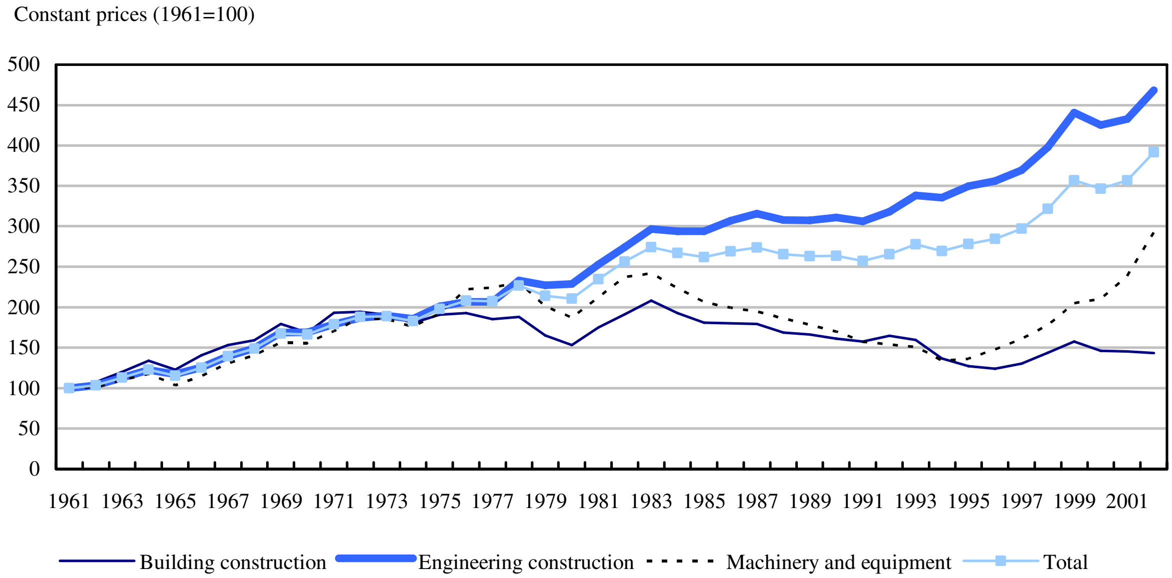
Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Figure 5
Capital per hours worked, total non-mining economy



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Figure 6
Capital per hours worked, total mining economy



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

The graphs above suggest that while the capital–labour ratios have been growing (although growth has slowed outside the mining sector) the amount of engineering capital available per worker outside the mining sector has been shrinking since the 1980s. Increases in overall capital per hour have occurred despite downward trends in infrastructure capital.

Engineering capital by sector

Trends at the level of the total economy may hide differences across sectors. Engineering construction relative to total GDP may fall because engineering construction is becoming less important in the sectors that make heavy use of this type of asset or because these sectors are becoming less important in the economy. To see this, note that

$$\frac{Cap_j}{GDP} = \frac{Cap_j}{GDP_i} * \frac{GDP_i}{GDP}$$

where Cap_j is the capital stock of type j (i.e., structures), GDP_i is GDP in sector i. Thus, the ratio of infrastructure capital stock in a particular sector to total GDP depends on how important infrastructure is in a particular sector ($\frac{Cap_i}{GDP_i}$) and how important this sector is in the total economy ($\frac{GDP_i}{GDP}$). This decomposition allows us to examine whether we use less, say, electricity infrastructure because the electricity sector is using less capital to produce a given output (the ratio of the electricity sector's infrastructure to its own GDP), or because the rest of the economy needs less electricity.

This section therefore asks whether there are differences in these components across sectors. Is the decline in overall infrastructure the result of declines in the importance of sectors that focus on engineering construction or is it because these sectors are decreasing in terms of relative importance? Does the commercial sector show a different trend in terms of its intensity of use of infrastructure than does the government sector?

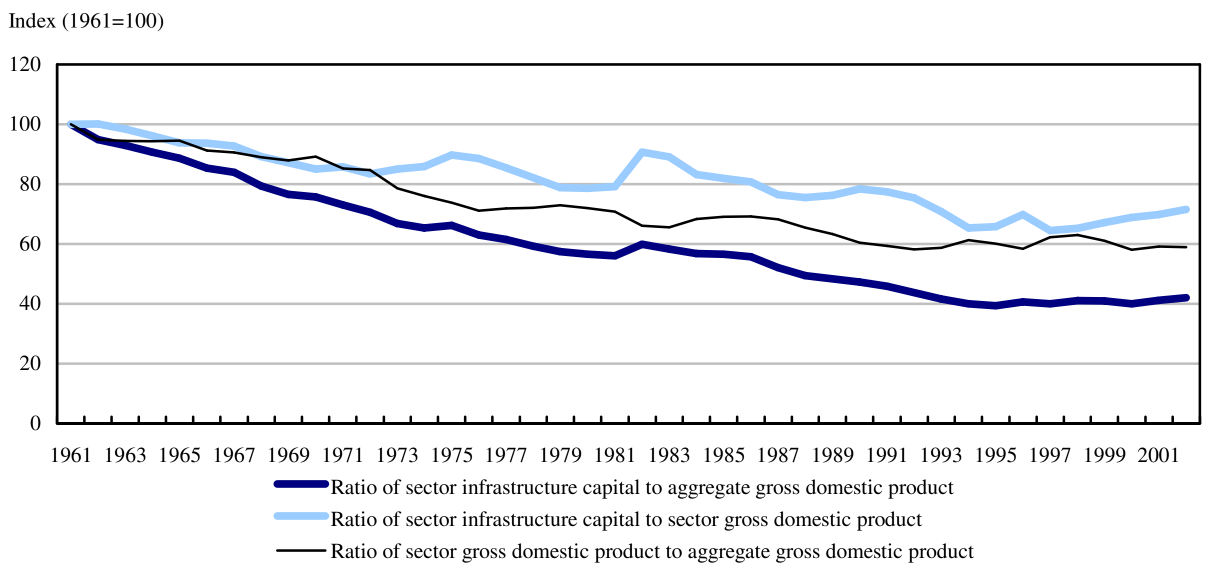
To help answer these questions, each of the graphs (Figures 7 to 14) plots the ratio of infrastructure capital (referred to here as structures capital) in a particular sector and the two components ($\frac{CAP_i}{GDP_i}$, $\frac{GDP_i}{GDP}$). The overall decline in any sector's infrastructure capital stems from a) whether it was decreasing or increasing the importance of infrastructure capital in producing its own output or b) whether its output was decreasing in relative importance compared with total output. Note that all capital and GDP figures are in current prices.

In the transportation sector, infrastructure has become less important over time relative to its own GDP and this sector's GDP has declined relative to total-economy GDP. The combined impact of both was to decrease the share of engineering capital relative to total GDP. In communications, engineering infrastructure also fell relative to own-sector GDP, but the sector as a whole became more important. Nevertheless, the net effect was to decrease engineering infrastructure here relative to total GDP. In waste, water and pipeline distribution, engineering infrastructure also declined relative to own-sector GDP though the sector became relatively more important. The net impact was to leave engineering infrastructure relatively unchanged. For electricity, infrastructure also declined in importance relative to own-sector output, though the importance of the sector's output tended to increase relative to the entire economy.

In summary, all the non-public administration sectors that were major users of engineering infrastructure saw their capital–output ratios decline over this period. The commercial sectors that were the heaviest users of infrastructure capital were increasing the intensity of use of capital in general over the period—especially that of engineering capital and the total of engineering capital and building assets that we have included in our definition of infrastructure. In light of the commercial motivations in place in this sector, it seems not unreasonable to conclude that infrastructure was becoming less important in the production process of industries like utilities, transportation and communications rather than to claim that all of these sectors were unduly running down their infrastructure assets simultaneously. This suggests that similar forces—either arising from technological change or relative price movements—were at work in all these sectors.

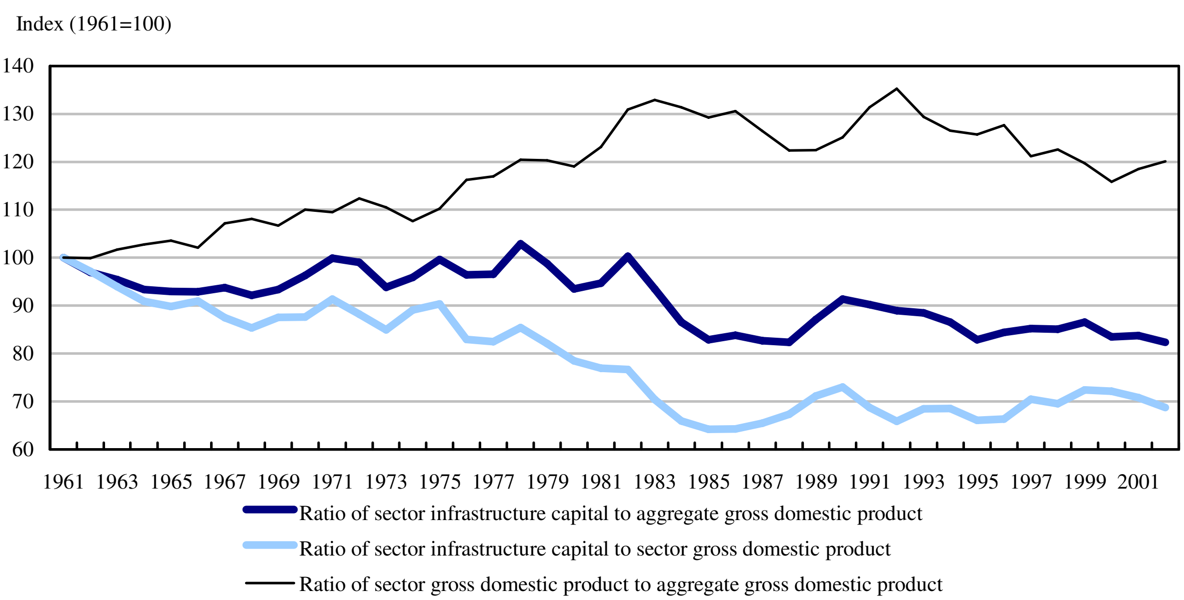
Infrastructure investment in the public sector has also decreased relative to total GDP (Figure 11). This is primarily because infrastructure has fallen relative to GDP in that sector—despite the fact that the public sector has increased its relative importance in the overall economy over this time period. But here we have to be cognizant of the manner in which output in the public sector is measured by the System of National Accounts. Since there are few goods sold at market prices in this sector, output is measured as the sum of factor payments—wages and depreciation. If output increased over this period relative to capital inputs, this stemmed from an increasing proportion of total expenditures coming from wages. The wages of doctors, nurses, teachers and public servants increasingly ate up a larger share of total public expenditures over this period. The public sector has substituted away from capital investments in the infrastructure field to other expenditures; much as has the commercial sector that also uses large amounts of infrastructure capital.

Figure 7
Transportation



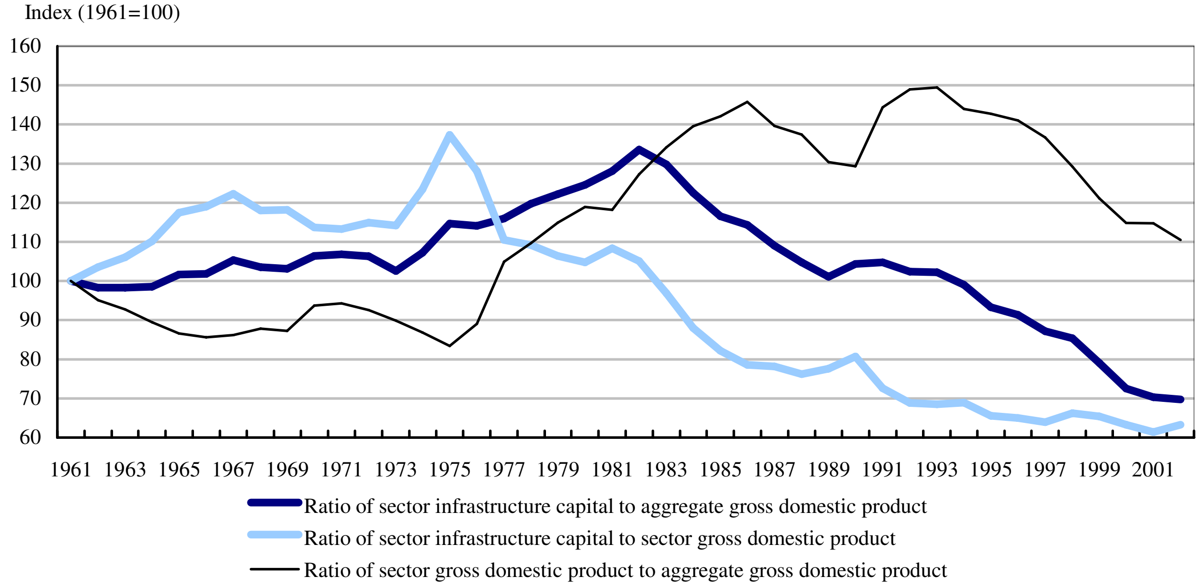
Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Figure 8
Communications



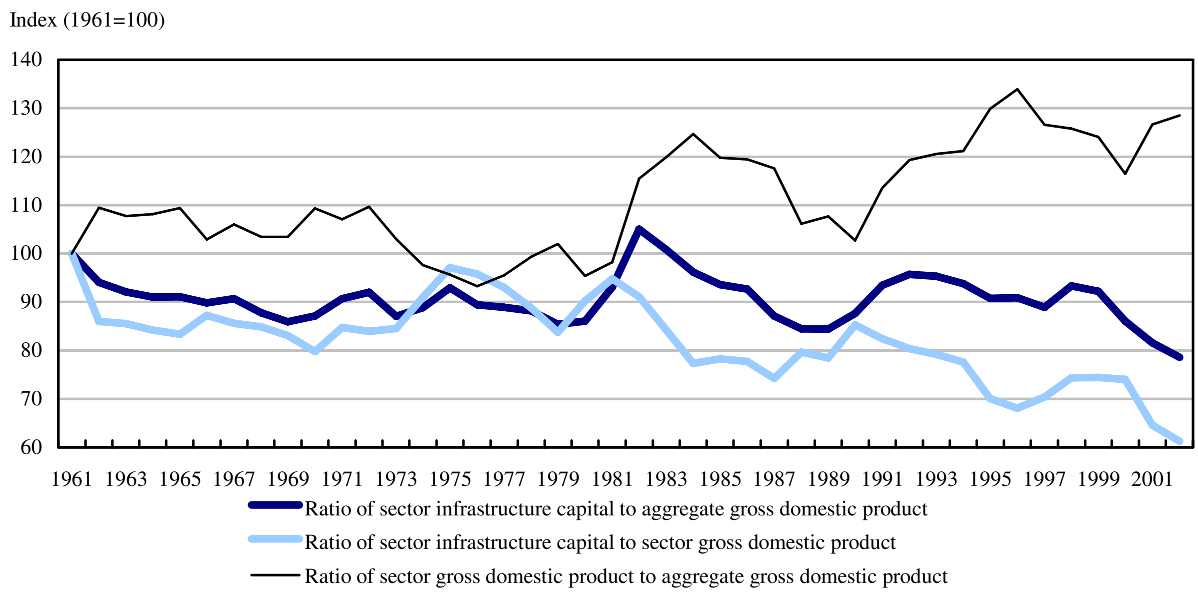
Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Figure 9
Electricity



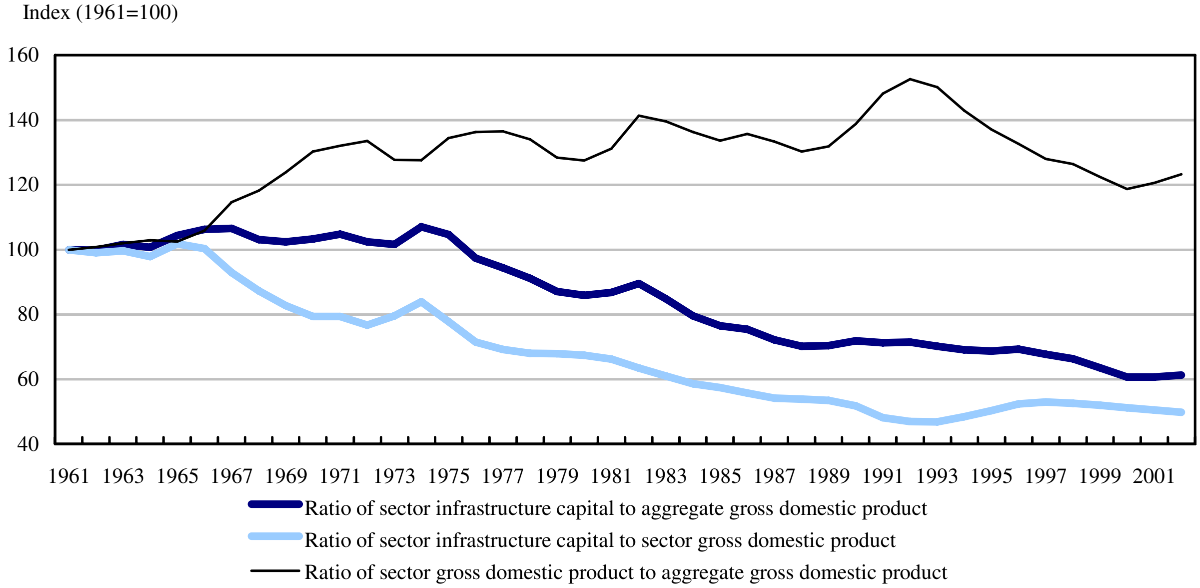
Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Figure 10
Waste, water and sewage and pipeline distribution



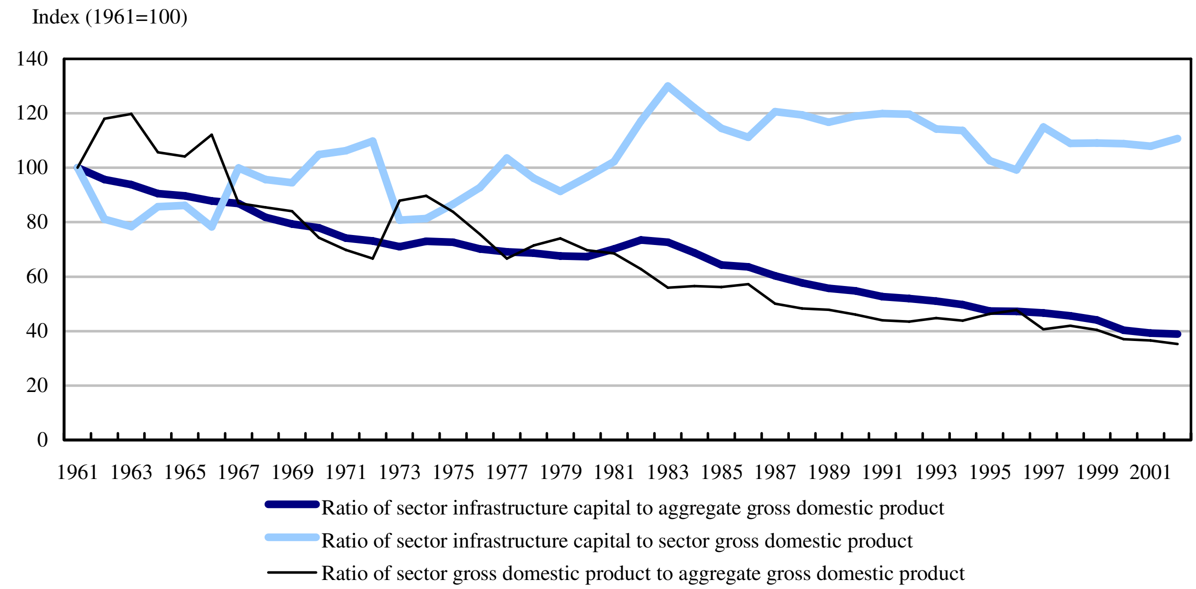
Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Figure 11
Public administration



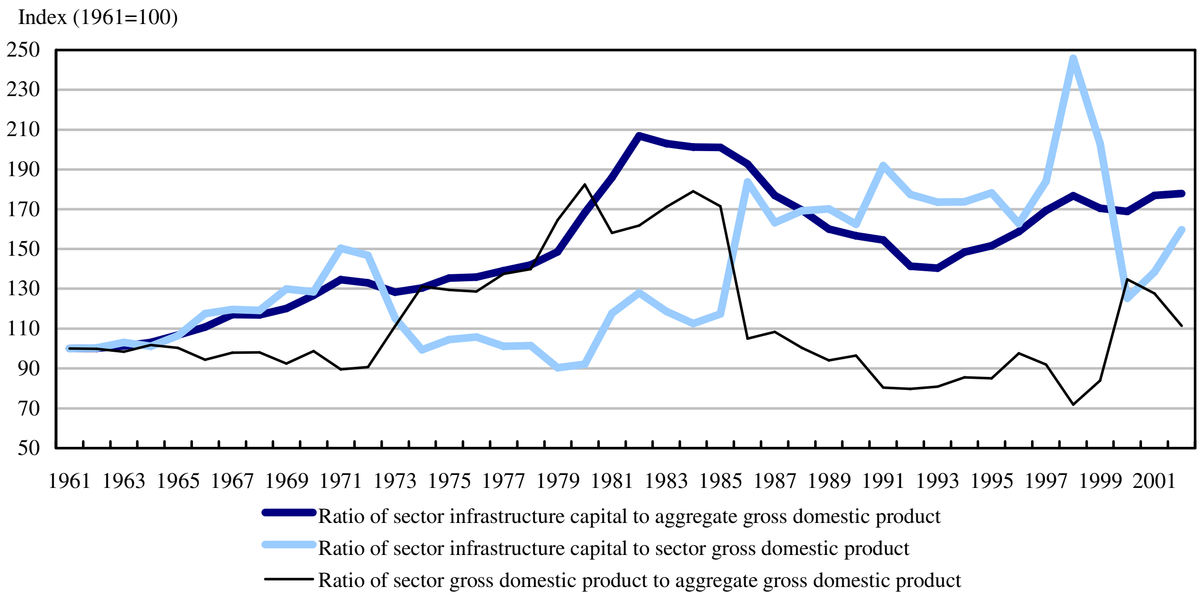
Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Figure 12
Agriculture



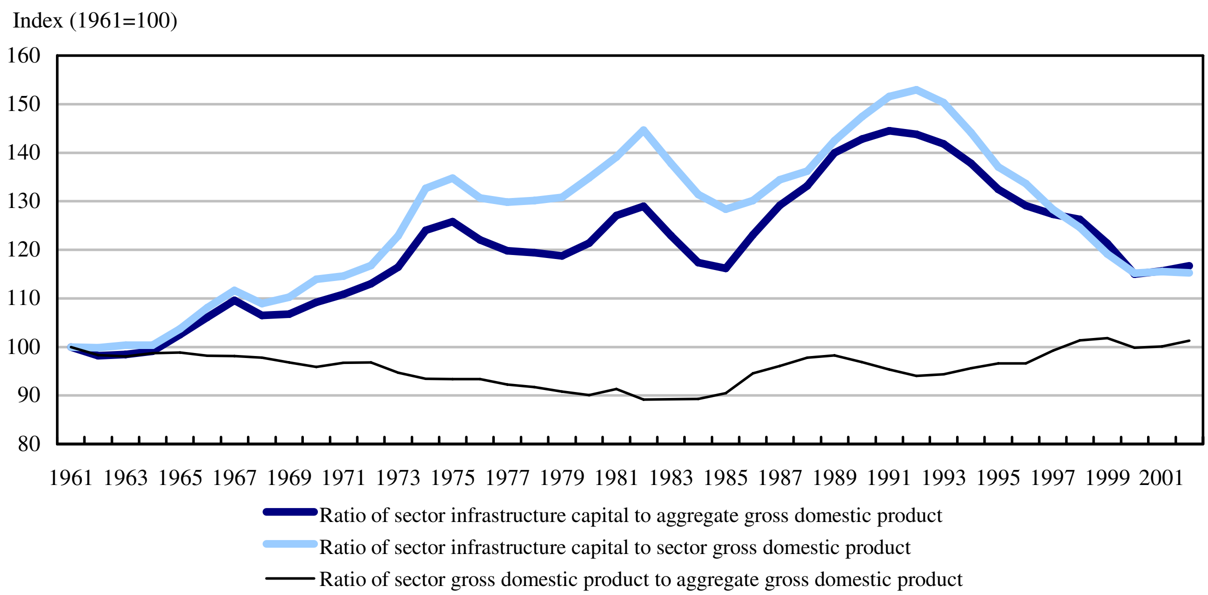
Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Figure 13
Mining



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Figure 14
All other industries



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Not all sectors have decreased their spending on engineering construction. As we have demonstrated earlier, the mining and exploration sector has increased its share of infrastructure investment over the last 40 years. In the mining sector, the ratio of infrastructure capital to total GDP has undergone two dramatic cycles, increasing in the late-1960s and then in the 1980s (Figure 13). The latter reflects the large amount of resources that have been placed in northern and offshore exploration.

Agriculture and other sectors have also seen an increase in their infrastructure capital relative to total GDP (Figures 12 and 14). The latter is the result of increased spending on irrigation. But neither of these sectors accounts for a very large share of total infrastructure spending.

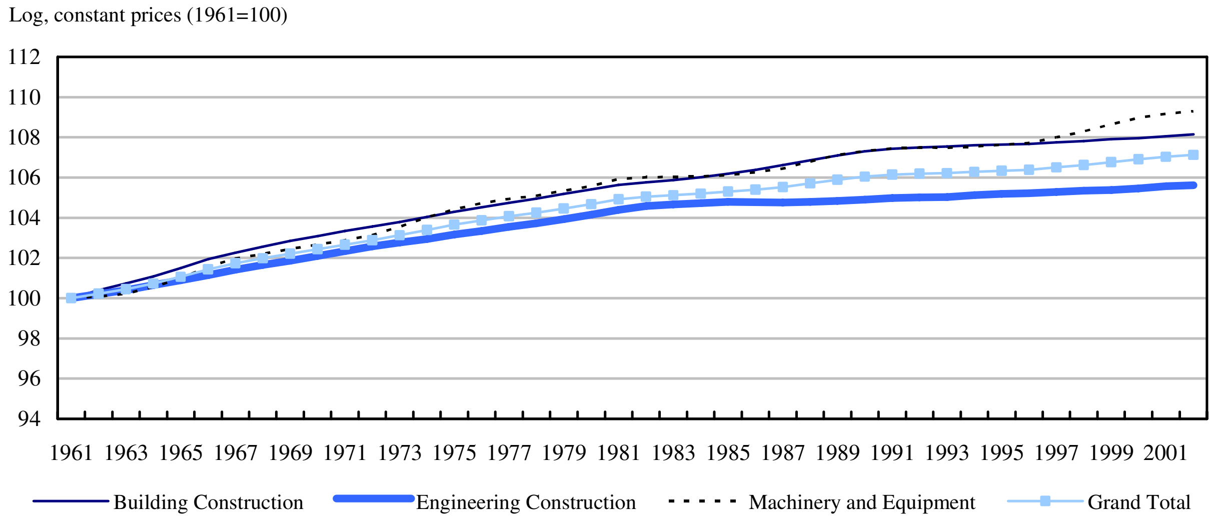
In summary, all the non-public administration sectors, with the exception of rail transportation, that were major users of engineering infrastructure saw their capital–output ratios decline over this period of time. Furthermore, these trends mirrored those of the public sector. Few argue that the business sector (communications, transportation) is in the process of starving its production systems of capital. This suggests that similar technological forces associated with capital savings regarding the infrastructure resources used to produce output were at work in all these sectors.

7.2 Capital per capita

The previous sections have described how the amount of infrastructure has changed relative to total output and to other inputs. The empirical evidence reveals that the commercial sector has economized on this type of capital and that, while the total amount of capital required per dollar of output has remained relatively constant, the share of total capital devoted to infrastructure has fallen.

This should not be interpreted to mean that the total amount of infrastructure has fallen. Indeed, the growth in the various forms of capital depicted in Figure 15 indicates that infrastructure capital did not decline as such. Rather, this growth was just slower than other forms of capital.

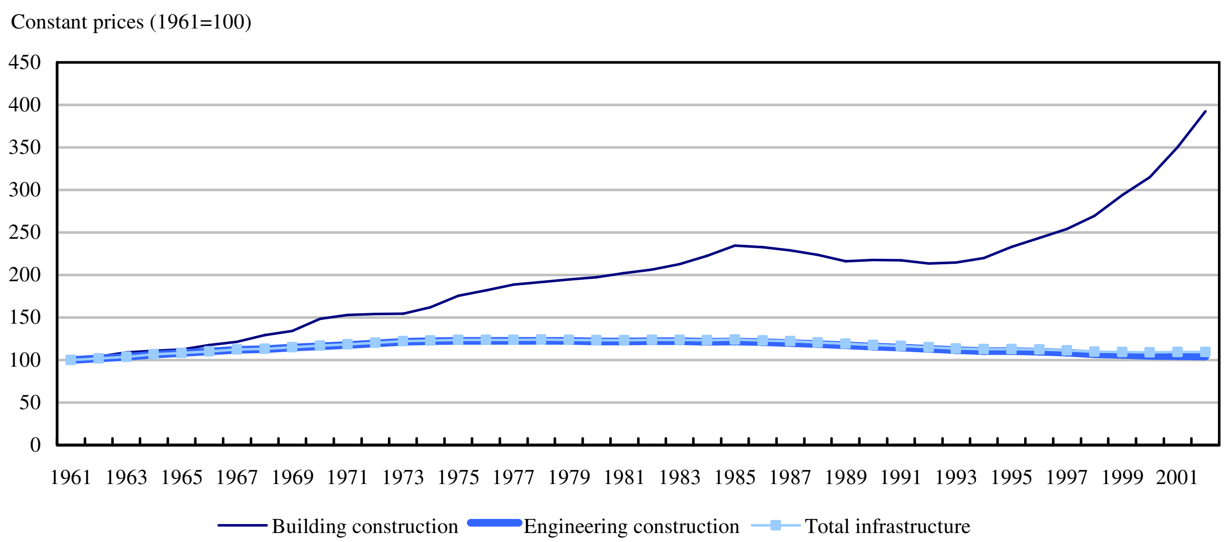
Figure 15
Growth of capital stock



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

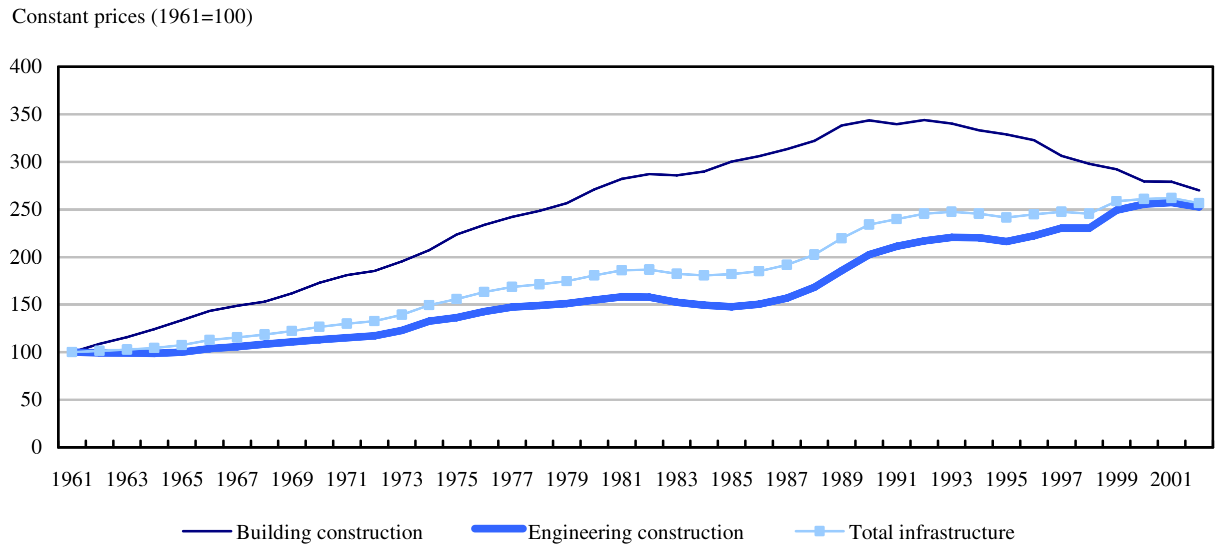
An alternate way of evaluating the amount of capital available in infrastructure is to calculate how much exists for each person in the country. The ratio of capital to population—capital per capita—tells us whether investments are keeping up with population growth.

Figure 16
Infrastructure capital per capita, transportation



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

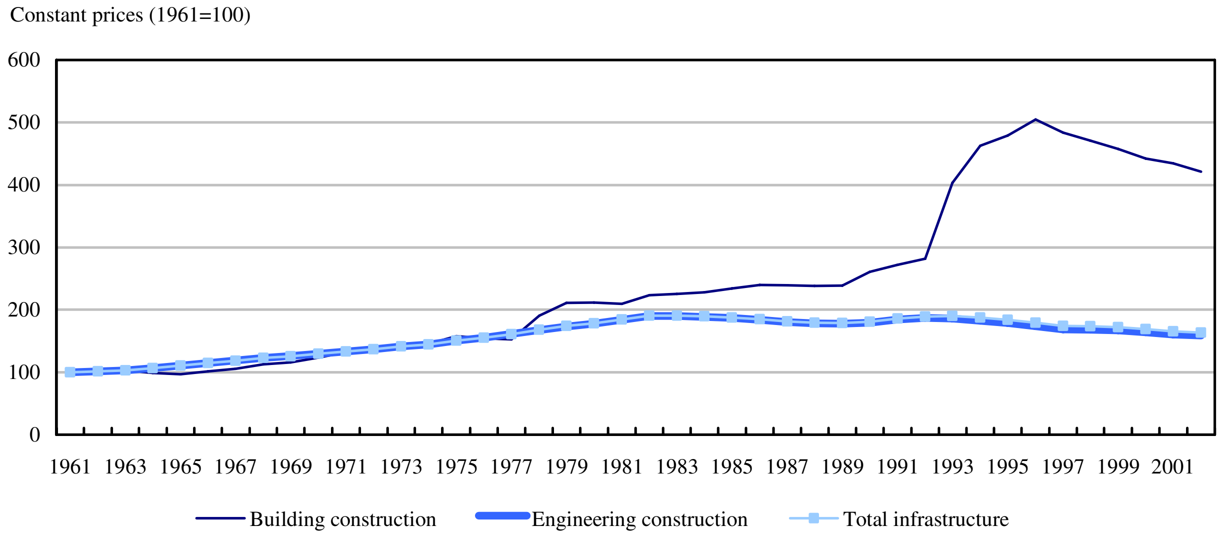
Figure 17
Infrastructure capital per capita, communications



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

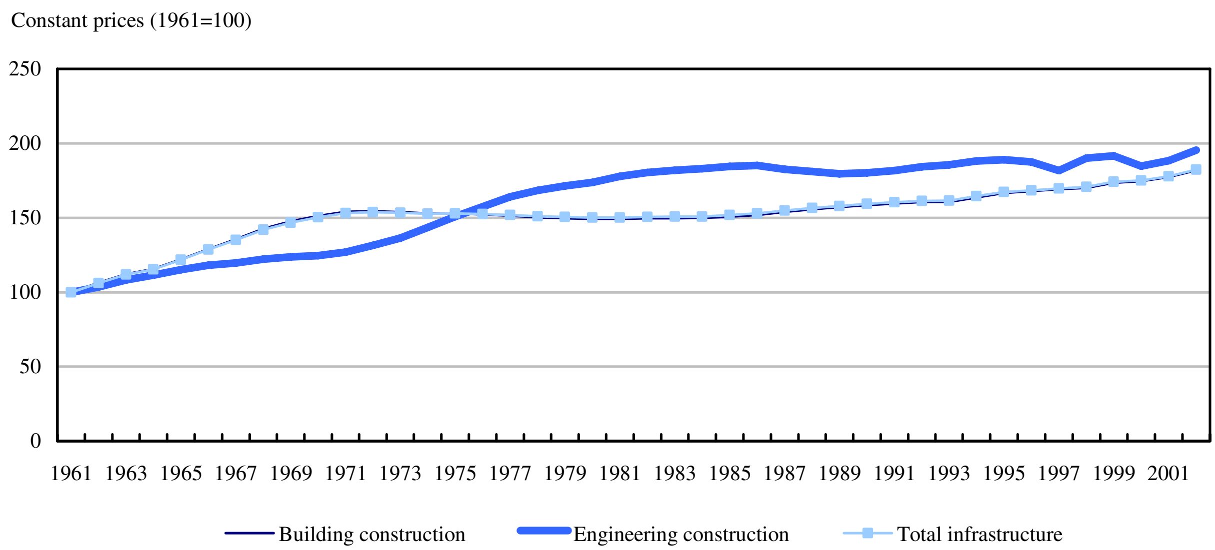
Figures 16 to 19 show the amount of fixed (engineering + building) capital, in constant dollars, per capita, by functional category and industry. In the transportation functional category, total transportation capital per capita rose from 1961 to the mid-1970s. It fell after that, because transportation capital in the public administration sector, after rising until 1973, levelled off thereafter, while transportation capital in the transportation sector fell continuously. The decline in the transportation sector is mainly due to a decline in capital in the business sector as the transportation sector substituted machinery and equipment for infrastructure.

Figure 18
Infrastructure capital per capita, waste, water and sewage and energy distribution



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Figure 19
Infrastructure capital per capita, education, recreation, culture and education, defence and public safety



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

The fixed capital assets of the other functional categories follow similar trends, regardless of the sector in which they are located. The value of public administration capital per capita in waste, water and sewage increases until the mid- to late-1970s, before levelling off in the early 1980s, and declining slightly after the mid-1990s. But here the value in the business sector continues to increase throughout the period. In energy and power, the business sector peaks in the early 1980s, as does public administration's capital in the same area.

All of this suggests that there has been no diminution in the amount of overall infrastructure capital serving the Canadian population. But there has been a levelling off in the growth rate. For the last 20 years, the economy has reached an apogee in terms of the amount of capital that is used to supply the demands of the public.

8 Comparisons with the United States

The Canadian experience with regards to infrastructure can be usefully compared with that of the United States. The two economies are closely linked and share a similar industrial structure. Comparisons of the two countries therefore allow tentative conclusions about similarities in terms of trends in the use of infrastructure capital, both in the commercial and non-commercial sector.

It is of course true that the two countries do not produce exactly the same mix of products. Nor are their historical growth records exactly the same. And therefore, they may have different infrastructure needs. But, by setting the experience of the two countries side by side, we can determine whether there are common forces affecting infrastructure.

We focus on five questions.

First, what is the relative growth of capital? In particular, does the growth in infrastructure spending follow a path that is different from other forms of capital? Finding similarities between Canada and the United States across most forms of capital would suggest that secular trends in infrastructure reflect a trend common to capital in general.

Second, were these trends the same across all industries? In particular, what was the experience of those commercial industries where infrastructure expenditures are high? Finding similarities across most sectors would suggest the same forces were present in many areas.

Third, was the rate of growth of infrastructure capital faster than the rates of growth of other forms of capital in both countries? Differences in rates of growth across types of capital indicate that one form of capital is being substituted for another. Finding that a similar type of capital substitution was taking place across the two countries once more would suggest a common cause.

Fourth, how did the growth in infrastructure capital per worker differ in the two countries? Growth in the capital-to-worker ratio generally is associated with growth in labour productivity. Examination of changes in the capital–labour ratio allows us to study whether the two economies were adding the same amount of infrastructure capital to aid workers in the production process.

Fifth, what was the difference across sectors in terms of changes in the structures capital–output ratios? This ratio measures capital productivity. Lower values of the capital–output ratio imply that an economy can produce more for the investments that it makes in machinery and structures. Finding similarities in the manner in which capital reacts to changes in output would suggest that the forces that were reducing the need for infrastructure capital in the production process (or increasing the productivity of capital) across the regulated sector were similar in the two countries.

In what follows, we use the terms 'infrastructure' and 'structural capital' or 'structures' as synonyms. Although a finer breakdown of structures by type (especially in building and engineering construction) may be preferable, we focus on structures as a homogenous category. This is done because the U.S. data provide information on only 15 types of structures (versus 98 types of structural capital in Canada) and they are not divided neatly into engineering construction and building construction, as they are in Canada's data. In addition, the U.S. general government's assets are presented using different categories than in other industries, which further confounds a more detailed analysis.

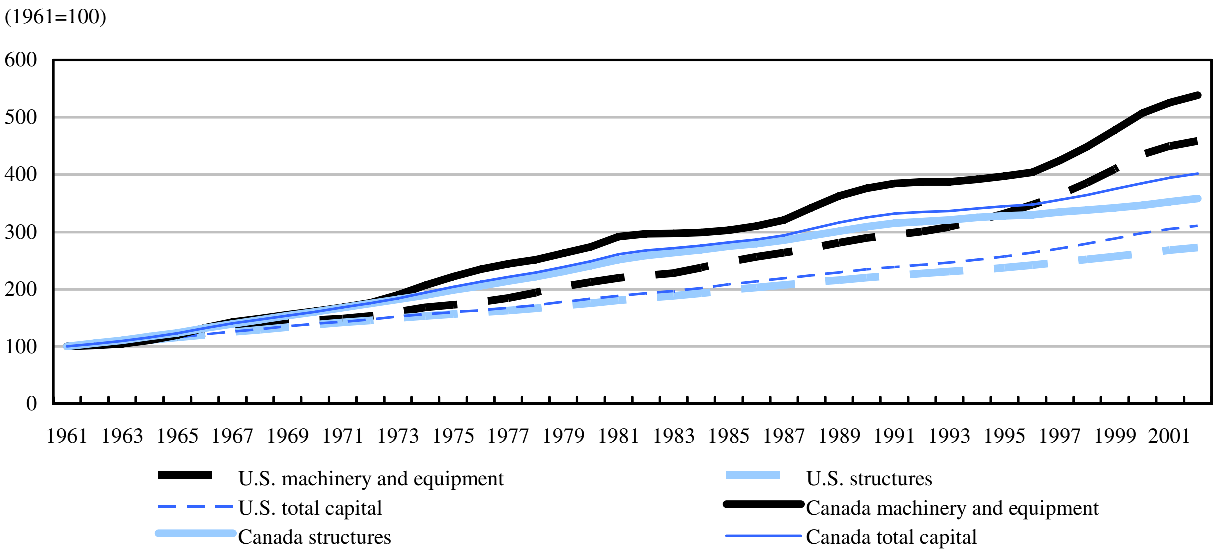
In this section, we make use of data on U.S. investment by industry that is taken from the Bureau of Economic Analysis but we use the perpetual inventory techniques and Canadian depreciation rates to calculate a capital stock that is comparable with that used for Canada.

8.1 Growth in capital by type[15]

Figures 20 and 21 compare the growth in Canadian and U.S. capital stock by type (structures and machinery and equipment) and industry.[16] The growth of Canada's capital stock (of all types) outpaced that of the United States' over the period after 1961. Much of Canada's faster growth, relative to the United States, occurred prior to the 1980s. After 1992, Canada's capital stock (of all types) has grown more slowly than that of the United States. It is perhaps Canada's slower growth in capital in the last decade of the sample that has sparked concerns about 'under-investment' in the north. But, while infrastructure growth slowed in Canada in the latter part of the period, the slowdown was part of a broader trend that saw capital growth in general slow down relative to the United States. The trend in structures is actually slightly better than the trend in machinery and equipment.

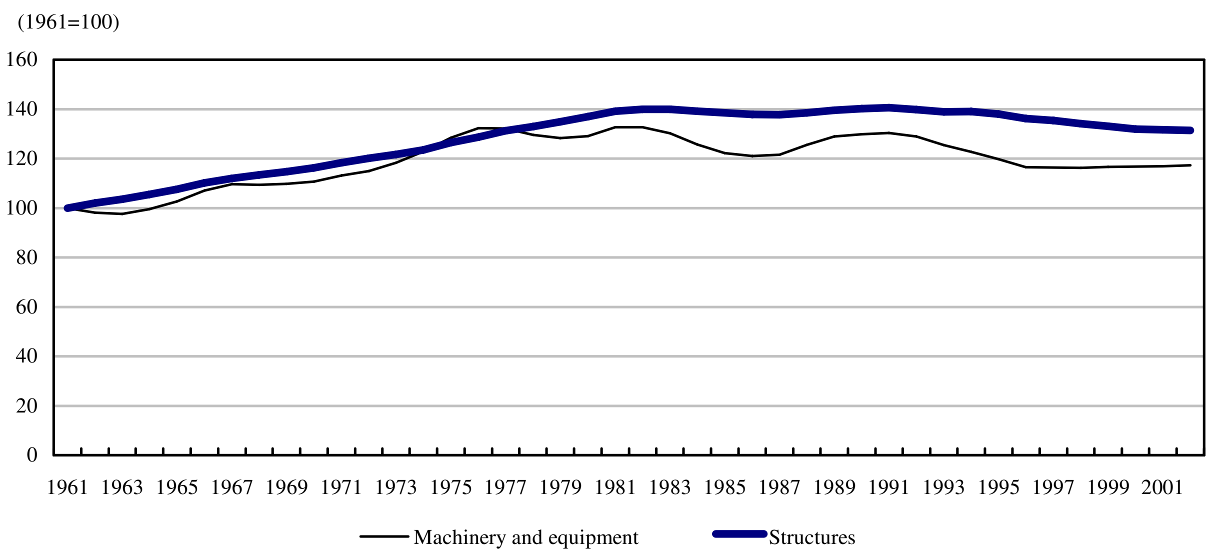
15. Capital stock in Canada and the United States are calculated using the perpetual inventory technique from investment data using the depreciation rates found in Statistics Canada (2007).
16. The graphs presented in this section for Canada may differ slightly from the previous section because sectors are aggregated in such a way as to be comparable with the U.S. aggregations used in this section.

Figure 20
Growth in capital, by type



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division; Bureau of Economic Analysis.

Figure 21
Growth in capital, by type, Canada relative to the United States



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division; Bureau of Economic Analysis.

8.2 Growth in structural capital by industry

A breakdown of the growth of structural capital by industry paints a richer picture of the evolution of the two countries' structural capital and allows us to evaluate whether these trends were the same across all industries—in particular, those commercial industries where infrastructure expenditures are high. It allows us to ask whether the differences that were found for the entire economy were present in most industries.

Figures 22 and 23 depict the capital stock growth in the 'infrastructure industries' in each of Canada and the United States. Figures 24 and 25 contain the relative growth rate of each sector in Canada to the same sector in the United States.

The largest differences between Canada and the United States come in the information sector, where, after 20 years of growing at roughly the same rate, U.S. growth outpaced Canada's during the early 1980s.

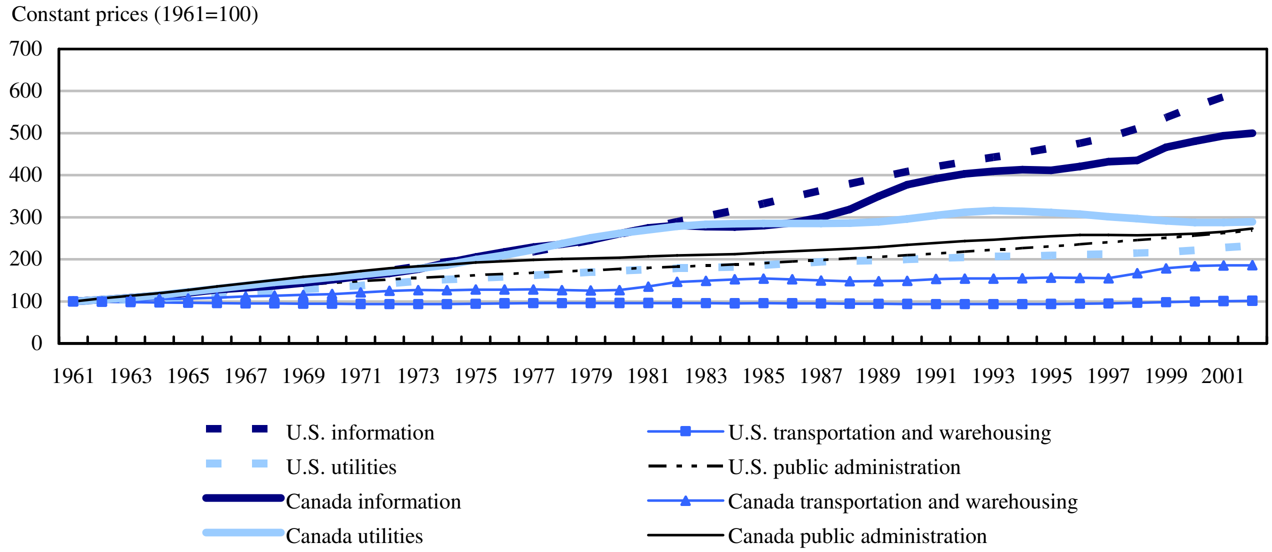
In the utilities sector, on the other hand, Canada's capital grew more than its U.S. counterpart until the early 1980s. But, whereas the U.S. stock of structural capital continued to grow at a steady pace, the growth in Canada was flat after 1982. This pattern is consistent with a buildup in capital in advance of demand for utilities in Canada that was not mirrored in the United States.

Canada's public administration structural capital grew slightly faster in the early part of the sample, but the U.S. annual growth rate increased to the Canadian level in the 1980s and exceeded the Canadian growth rate slightly in the 1990s.

The slowest growing infrastructure capital stocks for both countries were those of the transportation sectors. Structural capital in Canada's transportation sector did not quite double over the period; the U.S. transportation sector structural capital did not grow much at all.

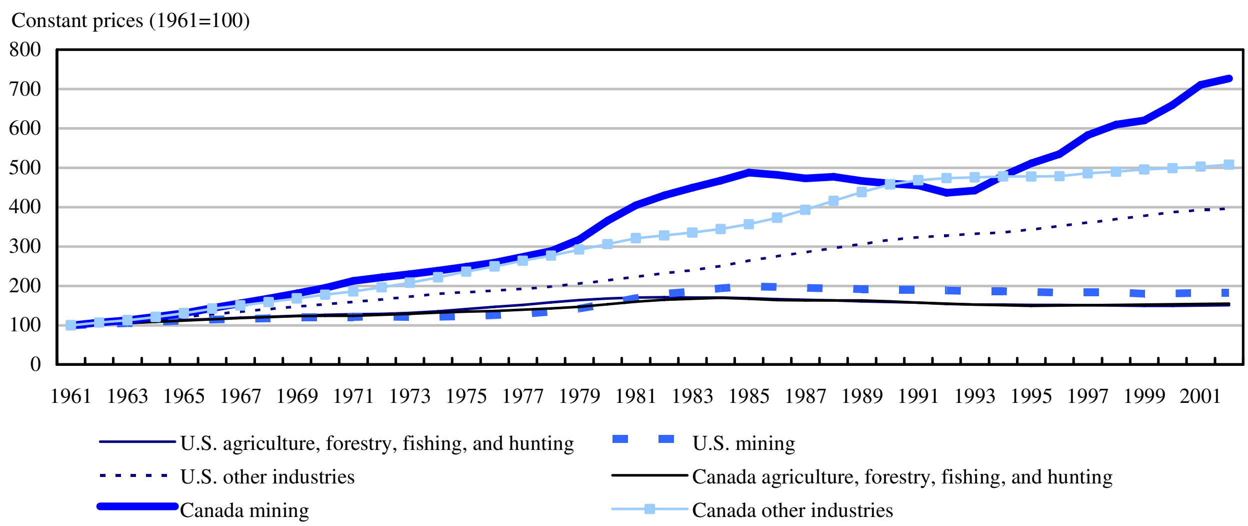
While there are variations across industries, a good number of the commercial industries follow the pattern where relative growth in Canada was higher earlier in the period and less so later in the period (Figures 24 and 25). Utilities follow this trend—that of higher at the beginning and lower at the end. The trend in the information sector is the same earlier in the period and falls behind later. This also occurs in 'other' industries. But in both transportation and mining, the growth in structures capital is higher throughout the period in Canada compared with the United States. Interestingly, the non-commercial public administration sector follows the same trend, with higher relative rates of growth earlier and lower relative rates later. The trend at the aggregate level is therefore borne out across most of the sectors where infrastructure investment is important. The overall trend that sees Canada doing relatively better than the United States earlier (from 1960 to 1980) and less well later (especially after 1990) is not due to peculiarities in only one sector.

Figure 22
Growth in structural capital stock



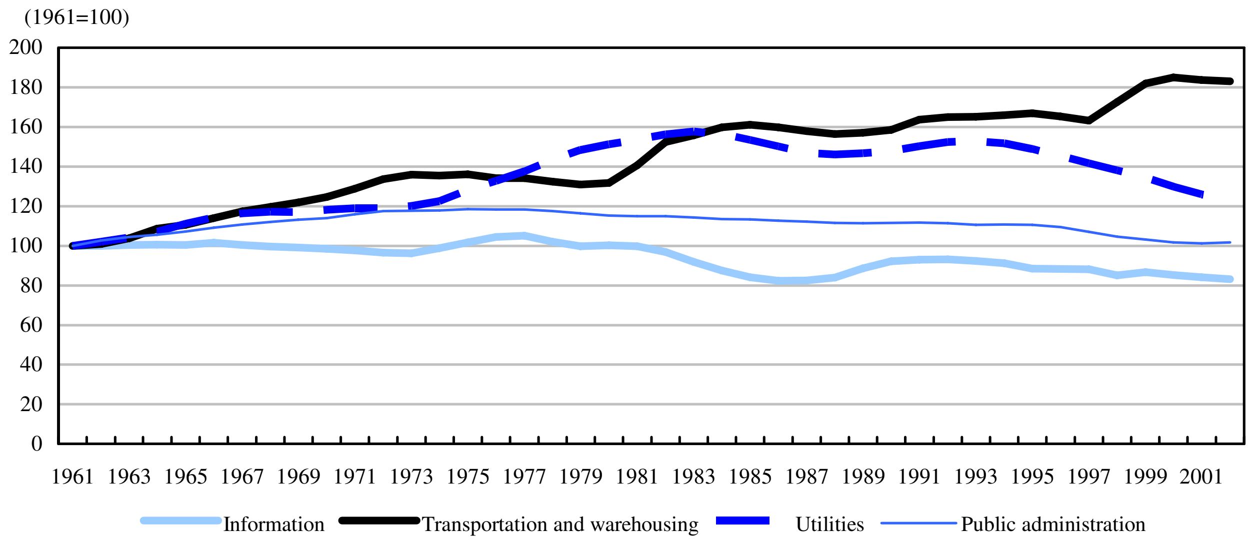
Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division; Bureau of Economic Analysis.

Figure 23
Growth in structural capital stock



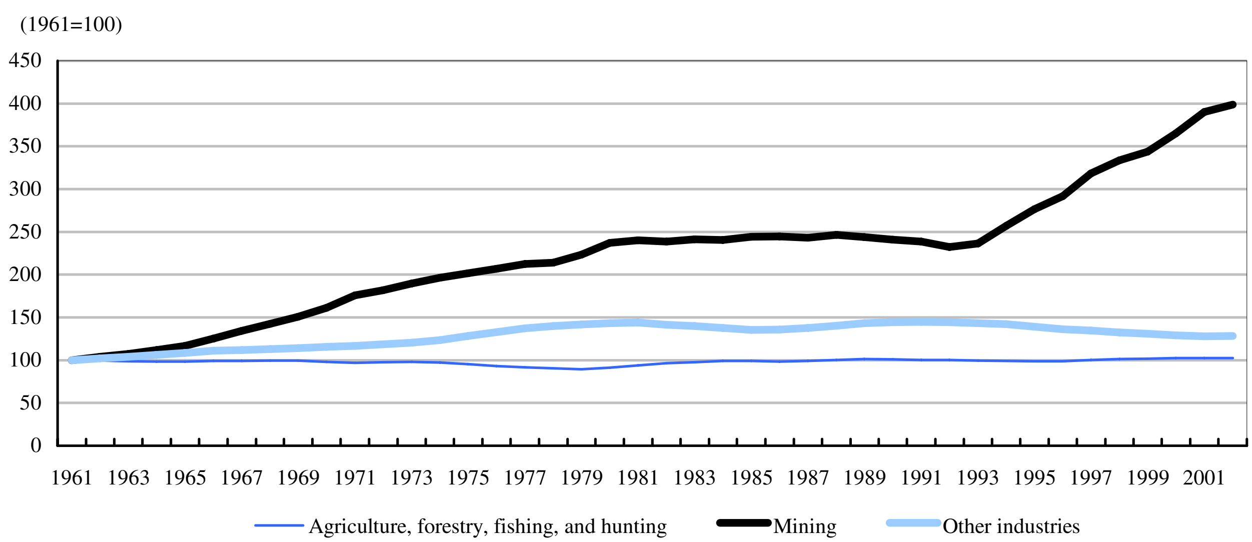
Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division; Bureau of Economic Analysis.

Figure 24
Growth of structural capital, Canada relative to the United States



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division; Bureau of Economic Analysis.

Figure 25
Growth of structural capital, Canada relative to the United States



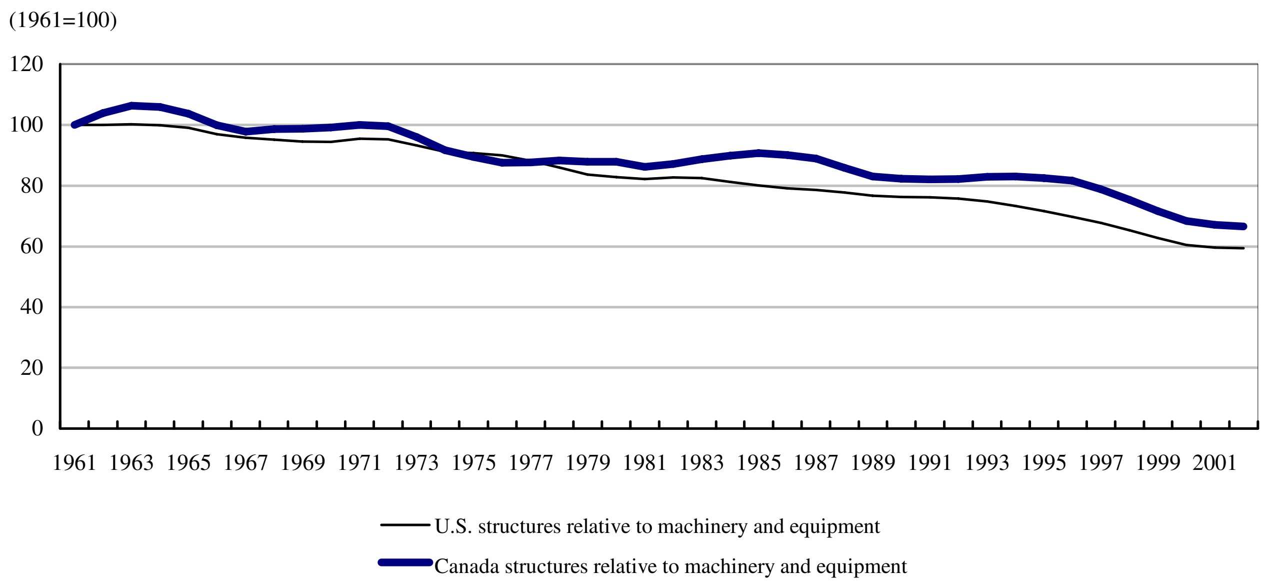
Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division; Bureau of Economic Analysis

8.3 Growth in structures capital relative to other factors of production

Infrastructure capital is only one input into the production process. It is combined with other forms of capital and with labour. Placing its growth in context allows an understanding of whether changes in infrastructure investment are being accompanied by substitutions across capital types or between labour and capital.

Figure 26 plots the relative changes in the structural capital versus machinery and equipment for both countries. Throughout the period, the price of machinery and equipment increased less than the price of structures. Substitution of machinery and equipment for structures might therefore have been expected. This was the case in both countries, though it occurred slightly more rapidly in the United States. Similar forces that served to reduce expenditures on structures, relative to other forms of capital, were at work in both countries.

Figure 26
Growth in structural capital relative to machinery and equipment



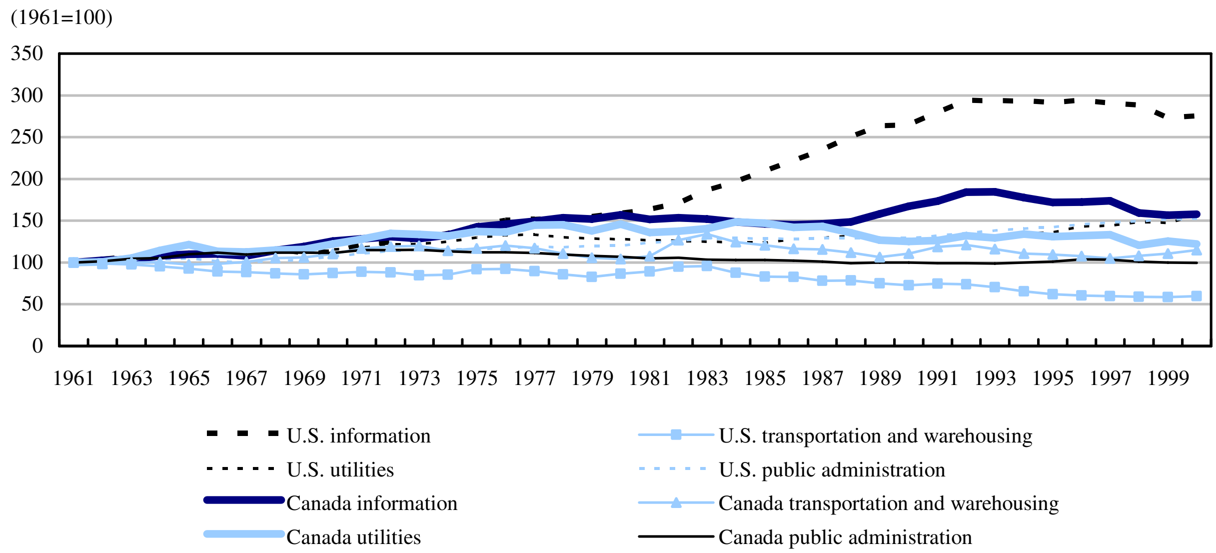
Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division; Bureau of Economic Analysis.

The growth in capital can also be compared with the growth in labour input. Differences in the two lead to changes in the amount of capital per worker. The growth in the capital-to-worker ratio is generally closely related to the growth in labour productivity; therefore, evaluating whether increases in infrastructure allowed capital–labour ratios to increase at the same or different rates in the two countries permits another useful comparison.

Figures 27 and 28 below show the stock of structures that workers have in each industry, measured by capital divided by hours worked. The most outstanding differences are in the communications sector, where capital per hour worked almost trebled in the United States from 1961 to 1991, with the majority of the growth coming after 1980. The growth in Canada's structural communications sector capital–

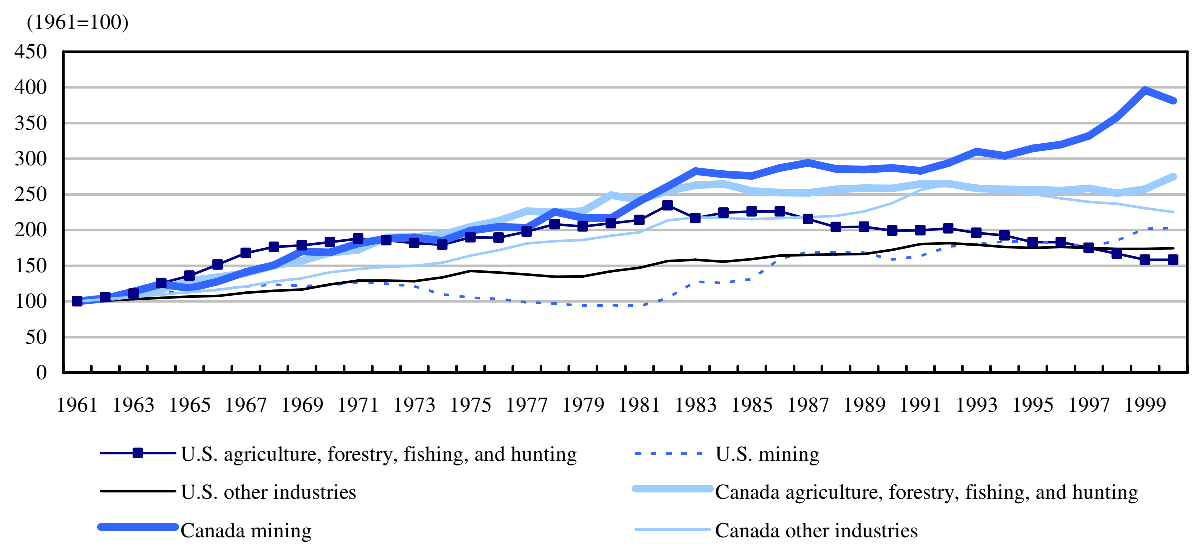
labour ratio matched that of the United States until 1980, but languished after that. These differences may be due to Ronald Reagan-era deregulation in the United States that had no counterpart in Canada.

Figure 27
Growth in real structural capital stock per hours worked



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division; Bureau of Economic Analysis.

Figure 28
Growth in real structural capital stock per hours worked



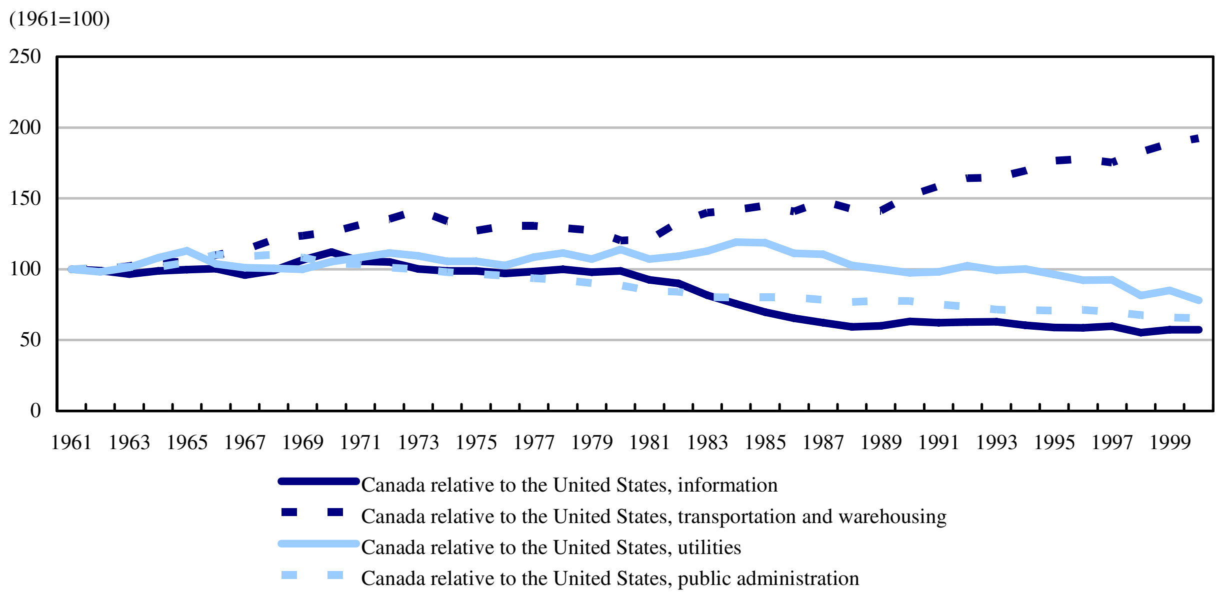
Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division; Bureau of Economic Analysis.

The differences in other sectors are less pronounced, but they are interesting nevertheless. Canada's transportation sector's structural capital per hour worked grew very little, but U.S. structural capital per hour in the same sector shrunk by almost half in the same period. These diverging patterns may be a sign that the U.S. transportation sector is becoming more labour intensive and less structural-capital intensive than its Canadian counterpart. There is a strong possibility that the differences are due to the structural capital intensive rail sub-sector, which has declined more rapidly in the United States than in Canada, and its replacement by the more machinery and equipment/labour intensive air and truck transportation sub-sectors.

The differences in public administration's structural capital per hour are minimal over most of the period. Canada's public administration's structural capital was flat relative to labour, as it was in the United States. In the late 1990s, growth in the capital–labour ratio in the U.S. public sector began to exceed Canada's.

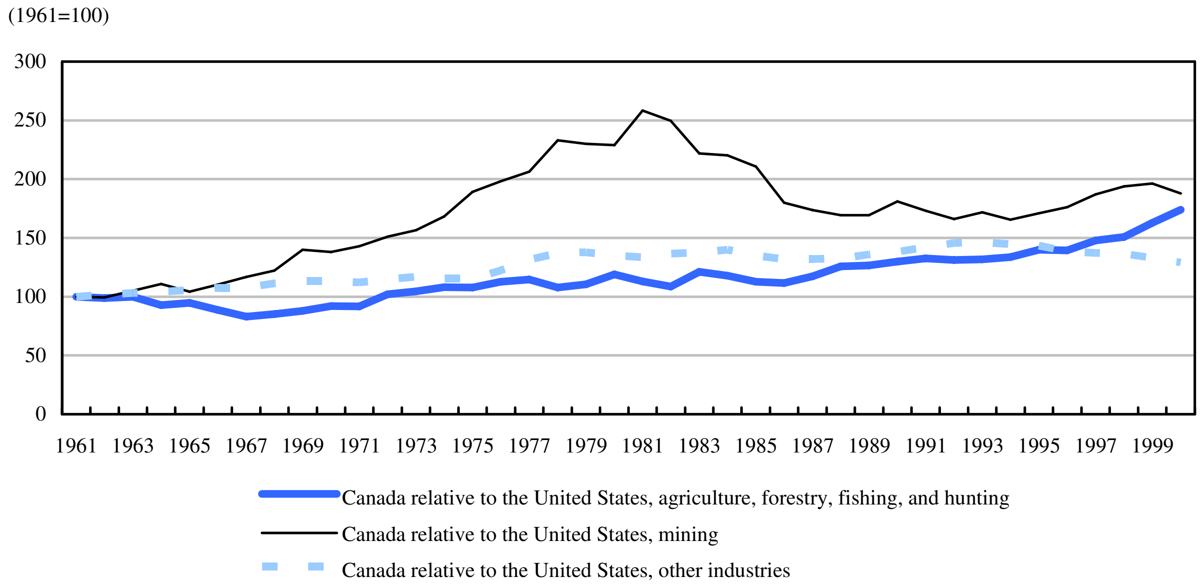
In terms of overall patterns, Canada's relative growth in the structures capital–labour ratio was higher during the period up to 1980, and remained at about the same level after 1980. At the industry level (Figures 29 and 30), this general pattern can be found in mining and public administration. In transportation, agriculture and 'other' industries, the difference between Canada and the United States widens over the whole period. In the information sector, Canada falls behind the United States after 1981.

Figure 29
Growth in real structural capital stock per hours worked by industry, Canada relative to the United States



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division; Bureau of Economic Analysis.

Figure 30
Growth in real structural capital stock per hours worked by industry, Canada relative to the United States



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division; Bureau of Economic Analysis.

8.4 Growth in output–capital ratios by sector

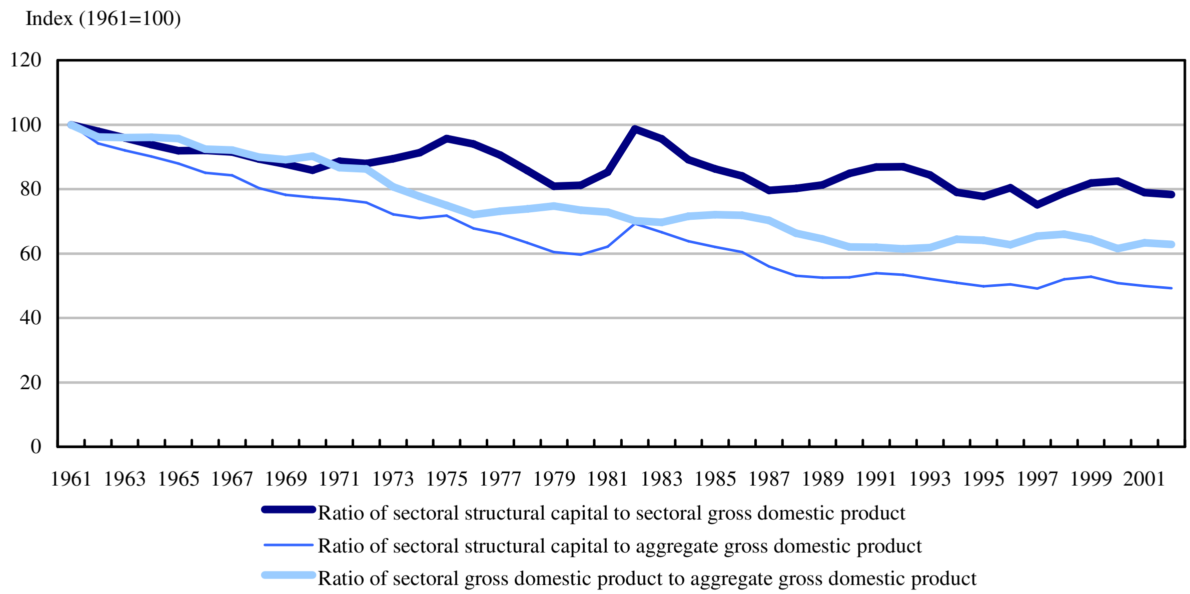
The trend in the overall ratio of structural capital to output depends on two separate components—the changing importance of those sectors where infrastructure spending is concentrated (the share of total gross domestic product (GDP) accounted for by each sector) and the changing importance of infrastructure investment to the production process within each of these sectors (their structural capital-to-output ratios).

This section examines the difference across sectors of the relative importance of each sector and changes in the structural capital-to-output ratios of each sector. It asks whether the differences in rates of growth of infrastructure reflected differences in the extent to which the individual sectors were growing or differences in the extent to which capital was being used more intensely.

One possible cause of differing trends in structural capital in the different 'infrastructure' sectors is that the sectors themselves were becoming more or less important in one country than the other. The figures below compare the sectoral GDP-to-aggregate GDP ratio, along with the sectoral structural capital-to-sectoral and aggregate GDP ratios. These ratios indicate (a) whether the sector is an expanding or shrinking part of the economy; (b) whether the sectors are becoming more or less capital intensive or (c) whether the combination of the two effects means that their capital is becoming more or less important to the aggregate economy.

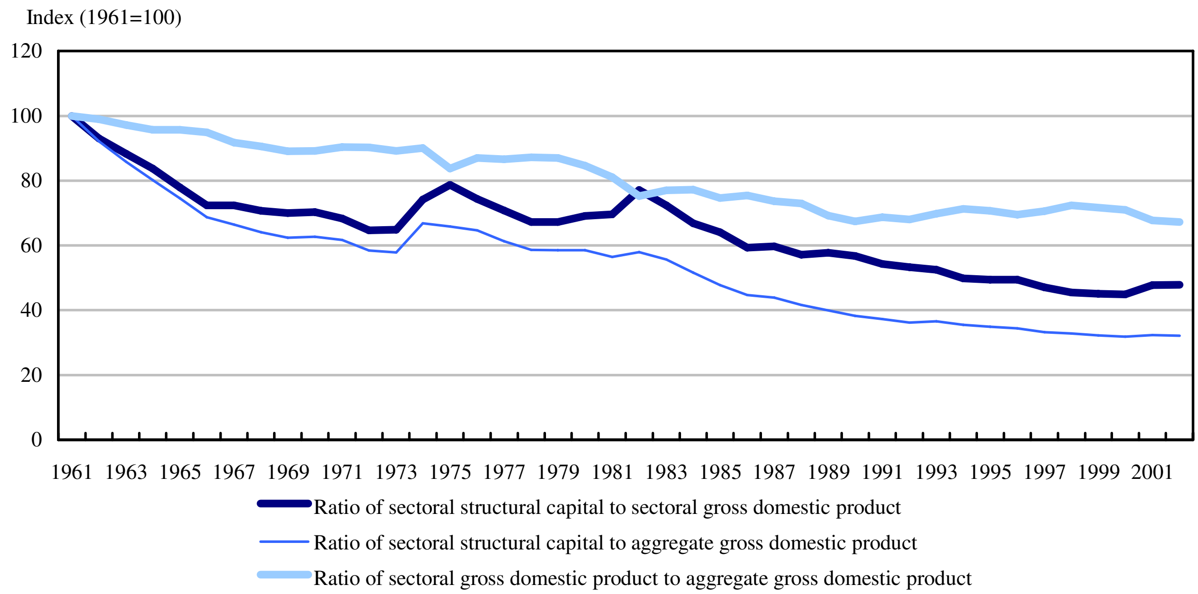
For example, Figures 31 and 32 show the evolution of the transportation sector in Canada and the United States, respectively. The trends for capital and GDP in each country are similar, but are much more pronounced for the United States. Canada's transportation structural capital as a fraction of aggregate GDP dropped by half; in the United States, by contrast, it shrunk by two thirds. The difference was not due to differences in the declining importance of the industry: this industry shrank slightly in both countries. But the U.S. transportation sector got progressively more from its structural capital than Canada did. Interestingly, the capital-to-sectoral GDP ratios follow the same trends up to 1982. Subsequently, with U.S. deregulation of the transportation sector, the U.S. ratio fell further and faster than it did in Canada.

Figure 31
Canadian transportation sector



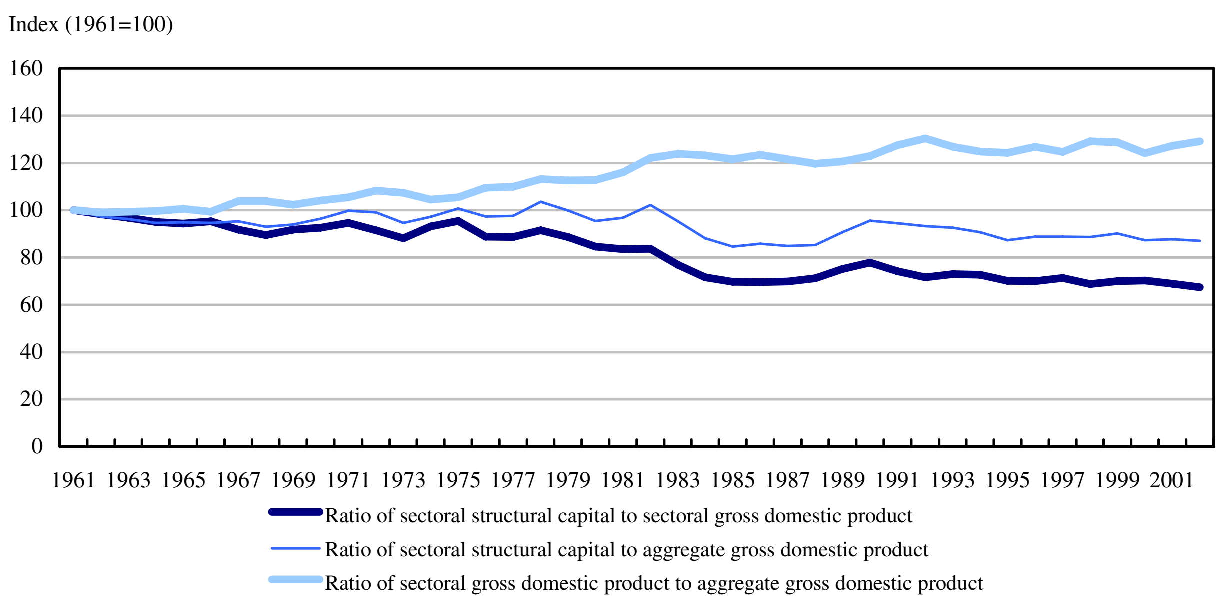
Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Figure 32
U.S. transportation sector



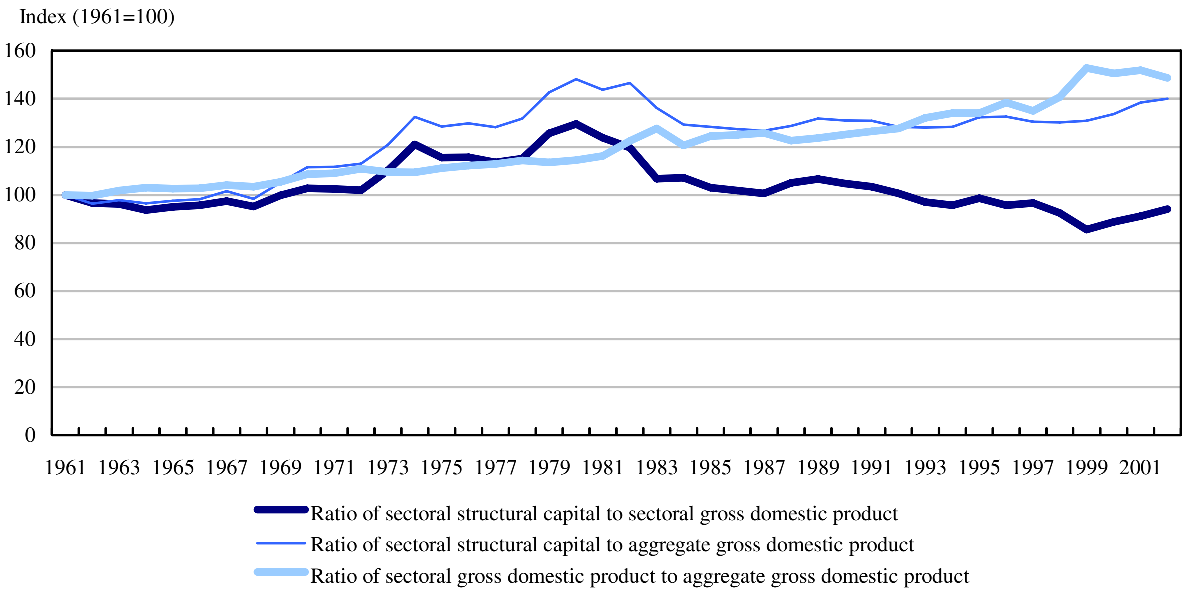
Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Bureau of Economic Analysis.

Figure 33
Canadian information sector



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

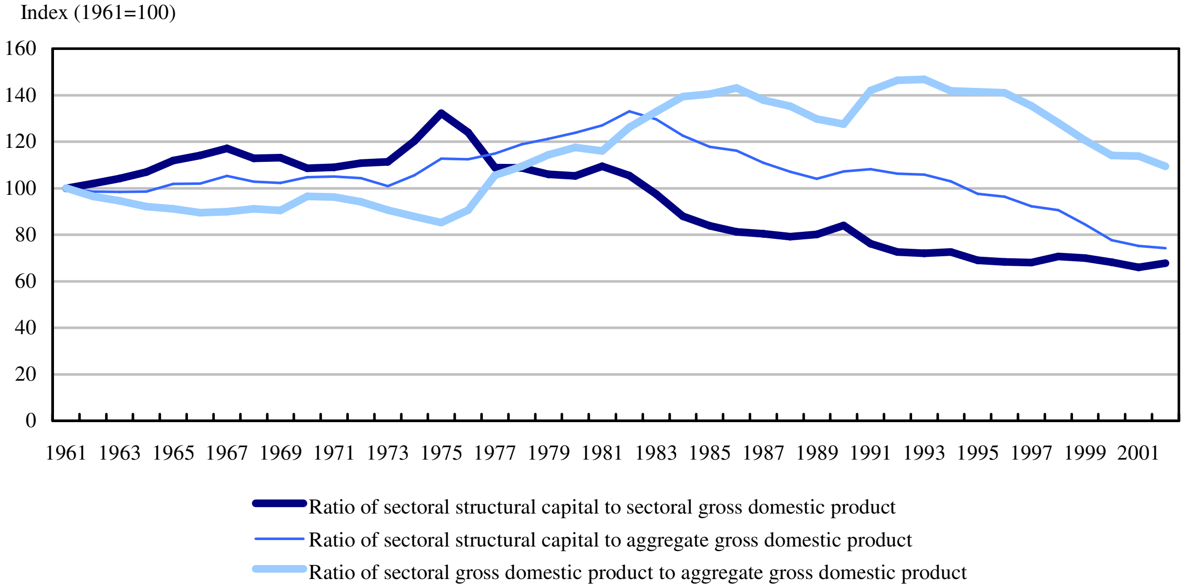
Figure 34
U.S. information sector



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Bureau of Economic Analysis.

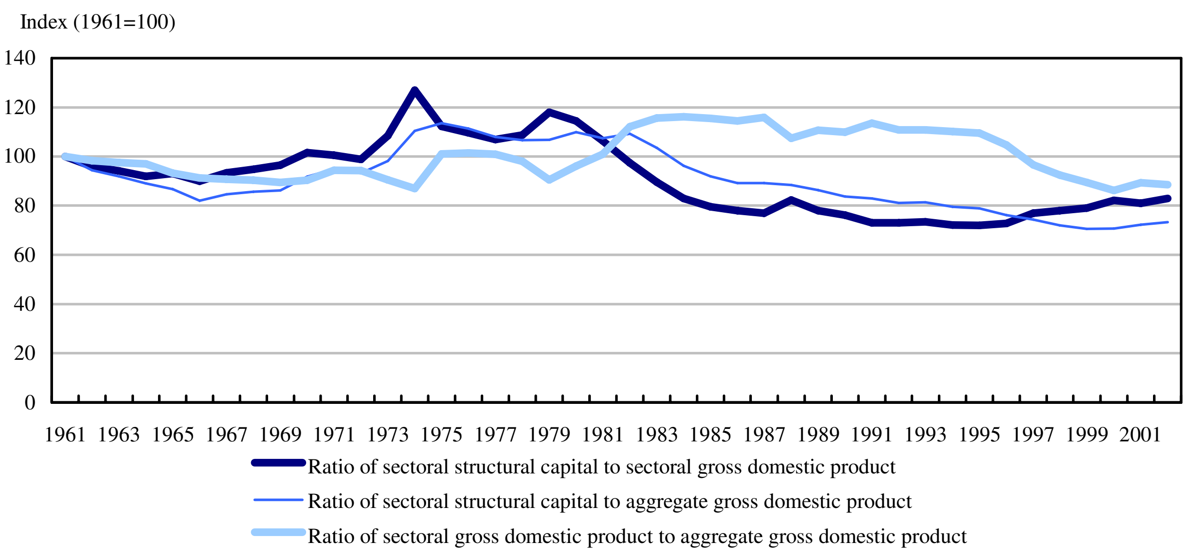
Figures 33 and 34 depict the evolution of the Canadian and U.S. information (communications) sectors. As noted above, they have diverged more dramatically than the other infrastructure sectors. The relative importance of their respective sectors grew apace until 1982 (each by just over 20%). The U.S. communications sector continued to gain importance after 1982 but this did not happen in Canada. The U.S. growth was preceded by growing structural capital intensity prior to the mid-1980s, whereas the Canadian sector used less capital per sector output in 2002 than it did in 1982. However, the post-1980 downward trend was similar in both countries. The divergence in sectoral-to-aggregate GDP ratios corresponds with U.S. deregulation in the early 1980s, but the growing sectoral capital-to-GDP ratio in the United States prior to that (compared with no growth in Canada) is more difficult to explain.

Figure 35
Canadian utilities sector



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Figure 36
U.S. utilities sector

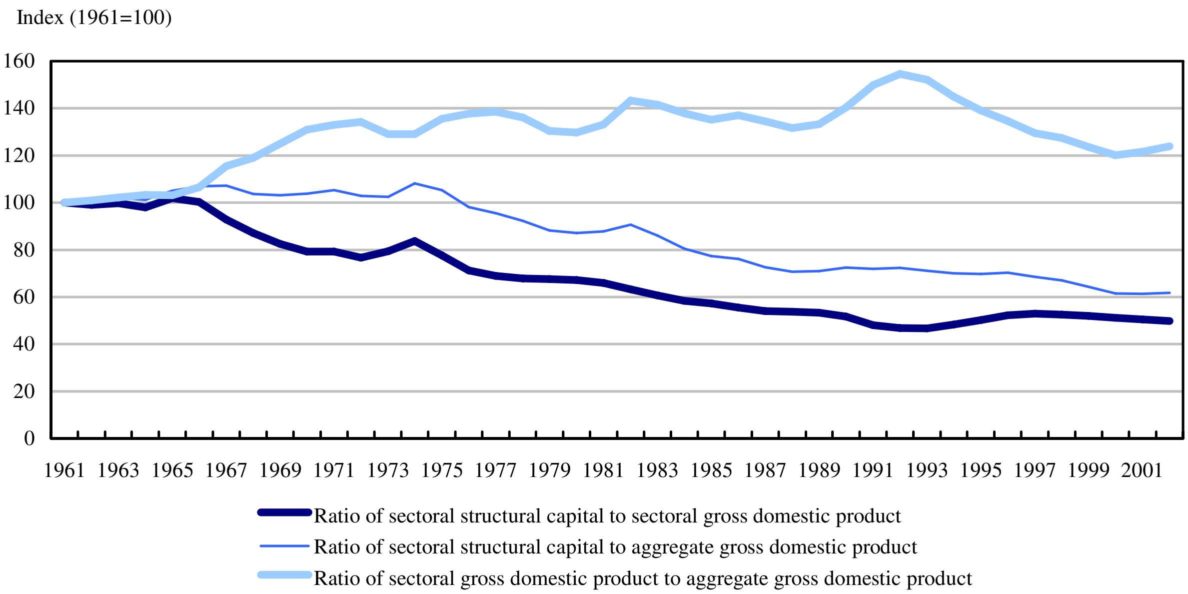


Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Bureau of Economic Analysis.

Figures 35 and 36 compare the evolution of structural capital and value-added in the utilities sector. The amount of structural capital as a percent of aggregate GDP dropped by about the same number of percentage points in both countries after 1982. In Canada it had further to fall, thanks to a rapid increase in capital relative to GDP from 1961 that was not matched in the

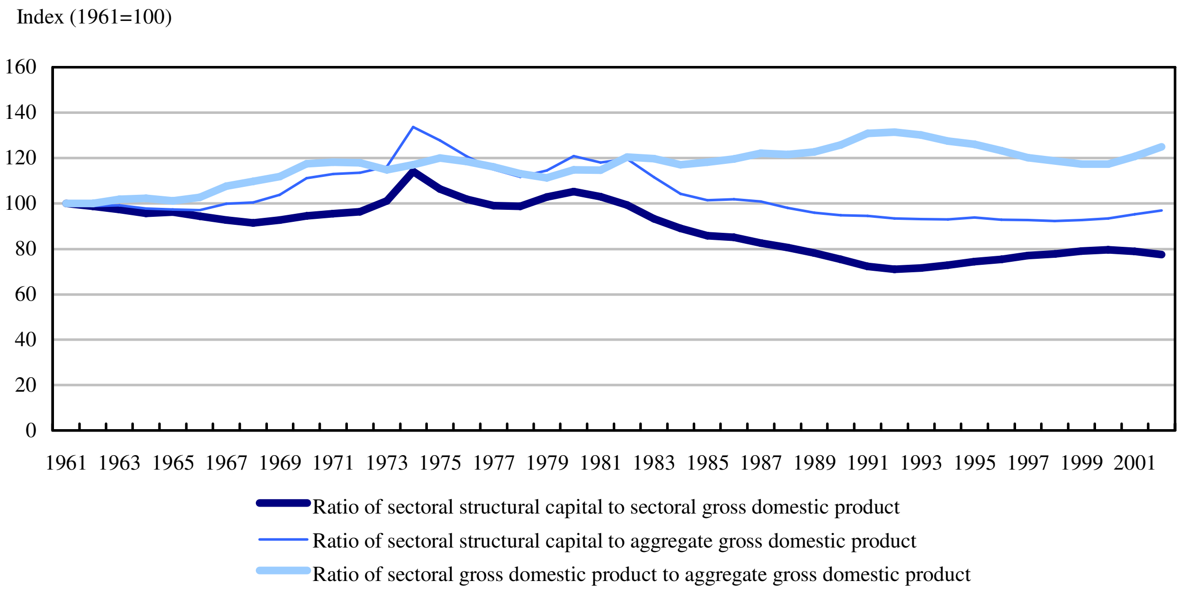
United States. This build-up preceded an increase in importance in the Canadian utilities sector. Structural capital to sectoral GDP rose from 1961 to 1975, before falling monotonically. The utilities sector's share of total GDP was stagnant until 1975, but rose rapidly until 1987, when it stabilized, and then dropped. These results suggest a build-up in structural capital in the 1970s in advance of the demand expansion in the 1980s and 1990s.

Figure 37
Canadian public administration sector



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Figure 38
U.S. public administration sector



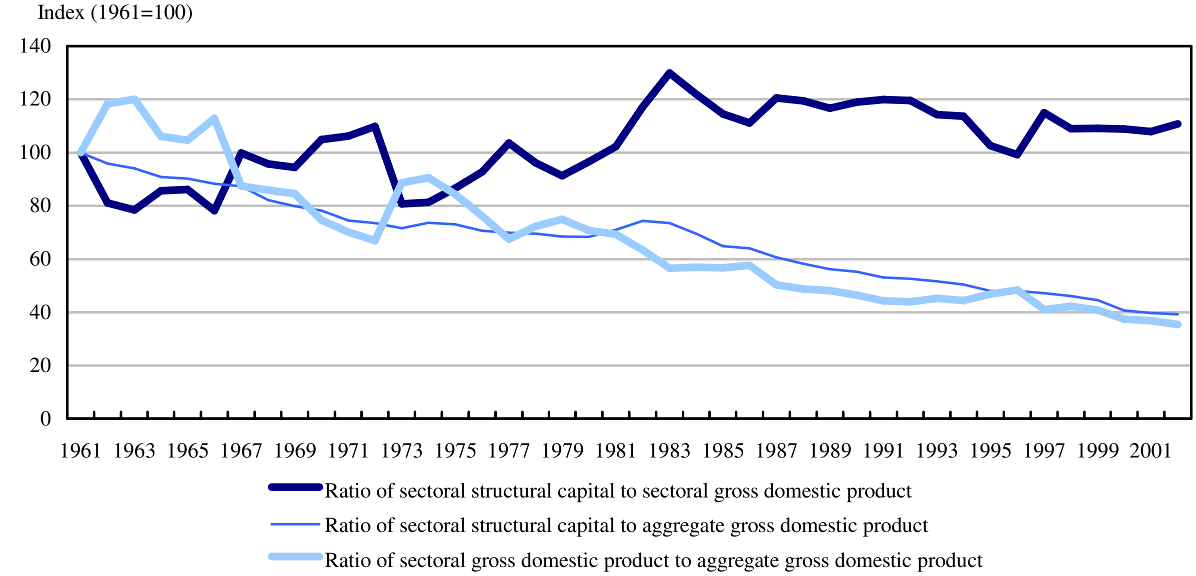
Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Bureau of Economic Analysis.

Trends were also similar in the Canadian and the U.S. public administration sector (Figures 37 and 38). Both sectors experienced a decline in the capital-to-GDP ratio, though the decline in Canada was slightly greater than in the United States. In the 1990s, this decline is reversed in the United States, whereas this did not happen in Canada.

In summary, many sectors showed similar trends in their relative importance—transportation and agriculture declines, information increases, utilities increases and then declines. In both countries, the importance of the public sector increases over most of the period, but then it declines in the 1990s. The similarity in the general trends substantiates the conclusion that the broad technological forces operating on the economy are similar in both countries.

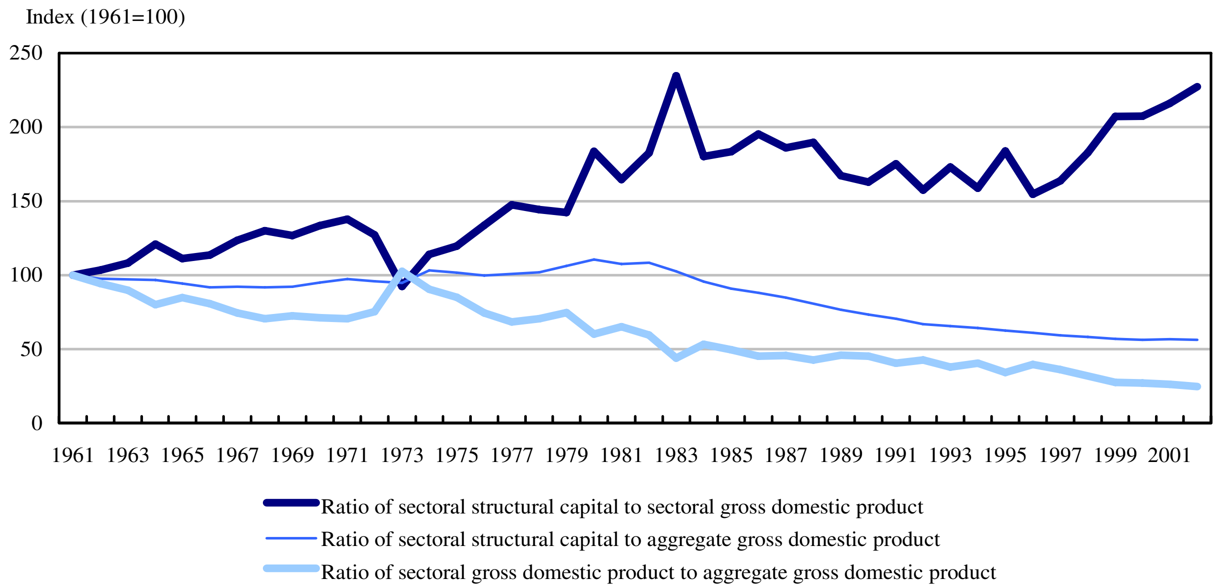
There were also similar forces at work in terms of changes in capital productivity (output per unit of capital) by industry. In a number of industries, capital per unit of output fell. This occurred in both countries in the transportation sector, in the information sector and in utilities. The U.S. decline is less for the information sector, about the same for utilities and more for transportation industries. These differences could be related to differences in composition of these industries (the relative importance of rail as opposed to air) or the extent to which incremental capacity requires a greater amount of investment (hydro projects like Churchill Falls or northern Quebec in Canada as opposed to additional coal-fuelled generators in the United States). While differences exist in terms of how capital reacts to changes in output, the similarities in overall trend suggest that forces—technological change and relative price changes—that were reducing the need for infrastructure capital in the production process (or increasing the productivity of capital) occurred across most of the sectors where infrastructure spending is concentrated.

Figure 39
Canadian agriculture sector



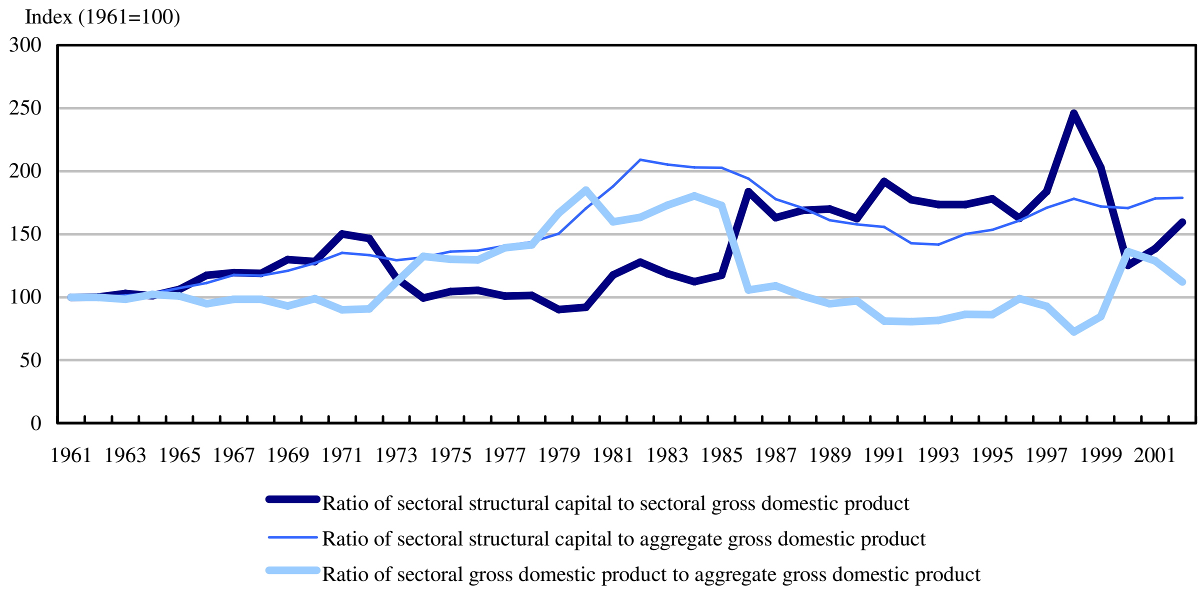
Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Figure 40
U.S. agriculture sector



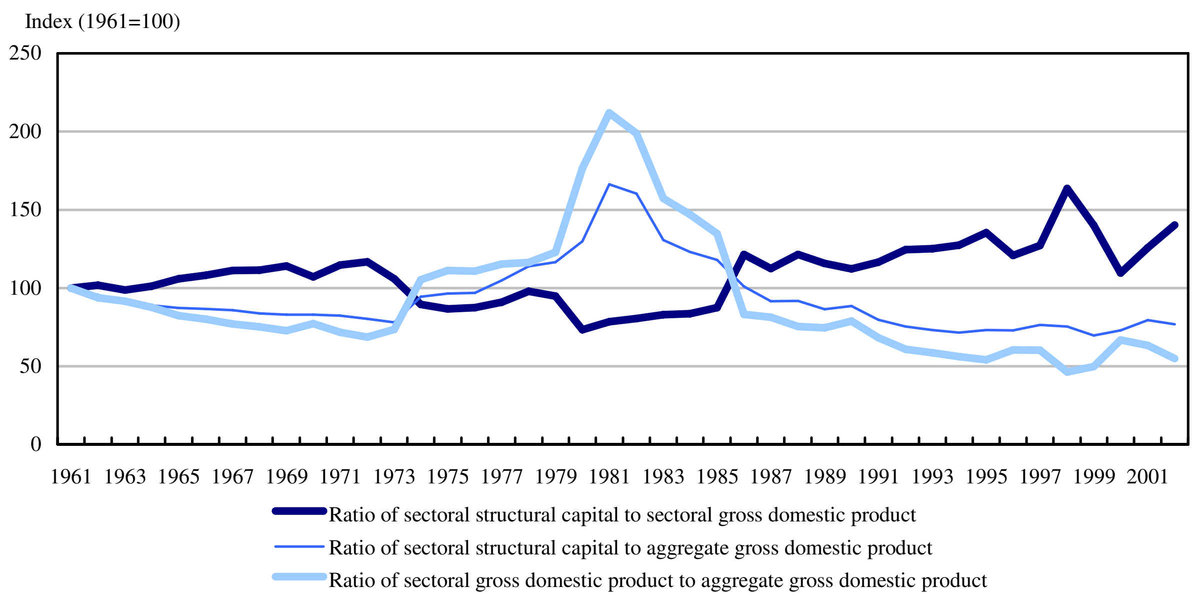
Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Bureau of Economic Analysis.

Figure 41
Canadian mining sector



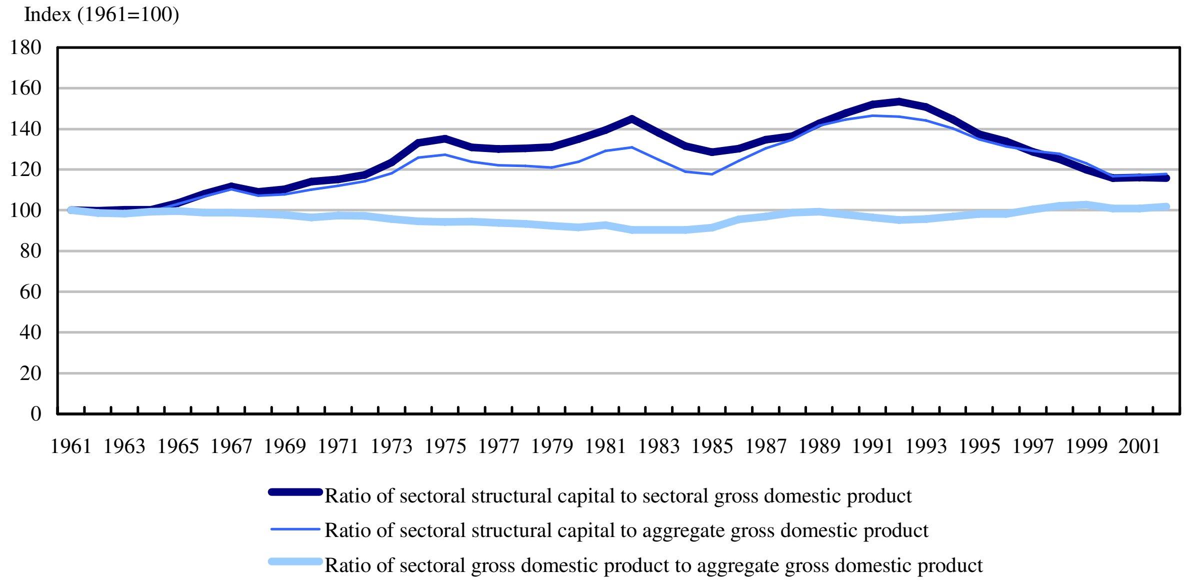
Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Figure 42
U.S. mining sector



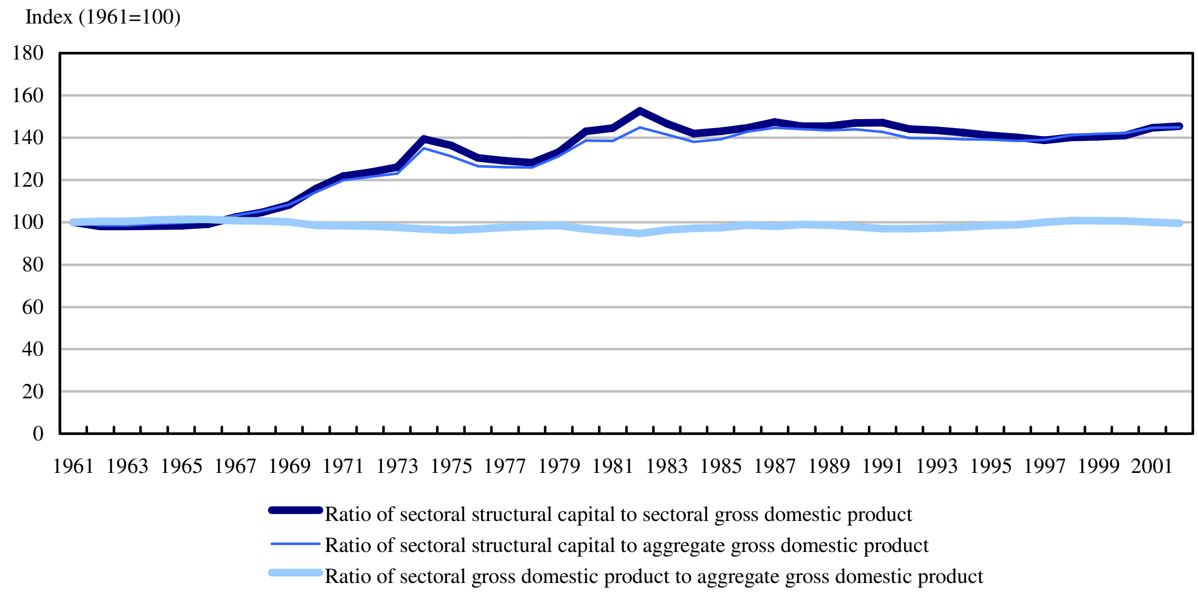
Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Bureau of Economic Analysis.

Figure 43
Canadian other industries



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Statistics Canada, Investment and Capital Stock Division.

Figure 44
U.S. other industries



Note: The tabulations were performed by the Micro-economic Analysis Division of Statistics Canada.
Source: Bureau of Economic Analysis.

8.5 Summary of Canadian-U.S. differences

Concerns about the adequacy of infrastructure often make reference to the long-term declines in expenditures in this area. But these declines may simply reflect normal forces at work within the economy. Over time, economies go through long cycles associated with the evolution of some sectors and a decline in others. Firms and governments substitute one factor for another as relative prices change. They decrease inputs (capital or labour) when technology improves the efficiency of input use. Assessing declines in any factor (infrastructure capital or otherwise) requires that analysts place changes in the factor input in the context of other changes that were taking place.

Our comparison of the Canadian infrastructure experience with that of the United States helps to develop that context. It shows that Canada has gone through two long cycles since 1960. From 1960 to 1980, growth was generally faster in Canada than in the United States and during this period, the growth in all forms of capital was faster in Canada than in the United States. During the post-1980 period, infrastructure spending slowed down in Canada relative to the United States but so too did spending on other forms of capital. Indeed, the growth in infrastructure slowed down less than did the growth in investments in machinery and equipment.

One of the explanations for a slowdown in infrastructure spending is simply related to the economic cycle in which Canada found itself. During this period, the resource economy that had boomed in the late 1970s was less vibrant and the infrastructure that was required to support it received fewer resources.

But there were other trends that have become evident in our comparison with the United States. First, there was a general substitution away from infrastructure capital to another form of capital (machinery and equipment). The relative price of machinery and equipment declined relative to structures in general. And both Canada and the United States increased the relative amount of machinery and equipment and concomitantly decreased the relative amount of structures in their capital stock. These changes should be expected in an economy where input use responds correctly to relative price changes.

Finally, a comparison of the evolution of infrastructure spending by industry shows that in both countries, the sectors that account for the majority of infrastructure spending were becoming more efficient in their use of capital or were gradually filling up the capacity of large investments that had been made in the late 1970s and early 1980s and were consequently using the capital more intensively. This was the major source of the reduction in the need for infrastructure capital in the commercial sector. While the trend to lower capital–output ratios in these industries was considerably greater in some sectors in Canada, it was nevertheless part of a North American trend.

9 Conclusion

Discussions of the amount of infrastructure that is required for our economy generally suffer from a) a lack of a meaningful definition as to what should be included under this category, b) comprehensive data on the amount of this asset and c) a basic understanding regarding changes in the amount of infrastructure that has been occurring. This paper has dealt with all three.

Much of the literature on public infrastructure tends to be frustratingly vague about its classification process. Public infrastructure studies are mystifyingly precise in choosing what assets should be considered, while being exasperatingly elusive about why they chose those particular assets.

When analysts do attempt to create a structure to help them define infrastructure, they commonly focus on functions of the products produced by industries in which infrastructure assets are located. We have chosen not to proceed with this route, arguing that it is problematic for two reasons. First, it is difficult to obtain agreement on which functions are 'foundational' in the infrastructure sense. Lists that attempt to do so using functions generally fail to establish any clear criteria as to what should be left out or what should be included. Definitions that refer to 'the public interest' leave the analyst with having to list areas where the public sector expends resources or where it legislates in the public interest. These areas vary country by country and jurisdiction by jurisdiction and therefore do not provide universal standards.

Instead, we define infrastructure as a set of assets possessing certain characteristics that give rise to specific economic problems that are pervasive across different economies. This approach relies on the economics of contract theory. In some situations, contractual problems lead to imperfect market outcomes like monopolies. These develop because of the characteristics of the production process that, in turn, are related to the nature of the capital assets that provide the foundation for production in these industries. In addition, the economic theory of contracts can be used to guide us in the choice of the characteristics of assets that create problems for the economic system—that either make for difficult and perhaps imperfect outcomes in the market system (natural monopolies) or that lead to public intervention.

This paper defines infrastructure as a set of fixed structures with specific characteristics—that have long useful lives; whose creation involves a considerable gestation period; that have no good substitutes in the short run; and that underpin the production of a flow of services, for which it is difficult to maintain inventories. These assets also have a special foundational role, supporting other factors of production.

Fortunately, the existing collection systems of Statistics Canada already use a taxonomy that enables us to identify assets with these characteristics. They fall under the general category that we refer to as fixed structures—consisting of engineering structures and buildings; however, determining which of them have a foundational role is more difficult. Determining which of the structures have qualities that make them public in nature is an even thornier task. The latter requires an analysis of why the commercial sector cannot resolve the contractual problems associated with infrastructure assets that require public intervention to guarantee adequate supply. Since that is not the task of statisticians—and its importance differs jurisdiction by jurisdiction—we forego any attempt to do so herein. Instead, we have restricted ourselves to highlighting the main features of infrastructure assets in general and classifying each of the engineering and building assets as to whether they belong to infrastructure or not. We do not go beyond a discussion of the rationale used by others to argue that these assets may also be considered to be public in nature.

We constructed a dataset on infrastructure assets for Canada from 1961 to 2002, and found that the overwhelming majority of tangible, produced structural assets are located in the public sector and in a handful of other economic sectors—electrical utilities, transportation, communications and water. These commercial sectors produce outputs that either are, or traditionally have been, the subject of government regulation in terms of their quantity or price.

Since the characteristics associated with infrastructure assets are also often associated with government intervention, the fact that most structural assets attract government intervention suggests that many of these assets are candidates to be included in a definition of 'public' infrastructure for this reason. That is, these assets do indeed have the characteristics that lead to contract failure—as is evidenced by the amount of government intervention in these areas (see Baldwin 1989). Infrastructure tends to be long-lived, and thus takes a long time to build. It is inflexible in its use and the services it produces have a low elasticity of demand. Their essential nature and their inflexibility often lead to contracting problems that create a demand for public sector ownership or involvement.

But although public sector involvement in some form is often a feature of public infrastructure, it is neither a necessary nor a sufficient condition to designate an asset 'public infrastructure' as a result of contract failure. The government often owns or regulates for reasons other than the ones we have stated. Furthermore, although public sector involvement is often provoked by difficulties in writing contracts between private parties, whether contractual failure occurs and public intervention is necessary in any situation will depend on institutions (especially legal systems) that differ across countries and over time. Thus, in some countries, governments may be actively involved in certain sectors over certain periods of time; in other countries, governments take a hands-off approach to the same sector because the commercial sector is able to resolve contractual problems in the infrastructure arena. The physical characteristics that define infrastructure assets are only associated with contractual 'problems,' not with universal market failure.

We believe that a definition of infrastructure must be consistent across jurisdictions and over time in order to be useful. Therefore, we do not rely upon public sector ownership, or government involvement, in determining which assets are 'public' infrastructure. We rely instead on the characteristics of the assets themselves that determine whether they are infrastructure.

As our data show, however, whether the assets or the sectors in which they are found are used to define infrastructure, a roughly similar picture emerges. There are a small number of three- and four-digit North American Industry Classification System industries that have most of the assets that can be characterized as infrastructure. In fact, the only decision that has a significant impact on the data is whether to consider only public sector assets, or whether to also consider assets in the small number of commercial sectors where these assets are concentrated.

Another useful feature of the method used here is that most of the engineering construction assets and many of the buildings can be classified by function. In this paper, we have adopted a specific mapping that allows us to describe which of the assets are devoted to transportation; communication; electricity; waste, water and sewage; natural gas and oil distribution; public safety; defense; education, recreation and culture; and health and social protection. This functional classification system is derived, with minor modifications, from a mapping that we propose from asset types to the Classification of the Functions of Government (COFOG) that permits us to examine infrastructure, not just by industry classification but also by purpose in the economy. Transportation, electricity and water make up most of the engineering infrastructure outside of mining.

The functional breakdown has two applications. It allows us to ask whether the patterns displayed by infrastructure are a function of changes in the economy or of changes in specific sectors. It also allows us to specify different relationships between different types of infrastructure. It is likely, for example, that transportation performs a different function in the economy than sewage treatment. Distinguishing between the roles of the various types of infrastructure should thus help empirical enquiries into the nature of infrastructure's role in supporting other factors of production.

The last section of this paper uses our dataset to examine the evolution of Canada's infrastructure capital since 1961. We do so, not by considering the amount of infrastructure in isolation, but rather in recognizing that infrastructure is just one of several types of capital and asking how changes in infrastructure compare with changes in other factor inputs (capital and labour). And we compare trends both in the commercial and the public administration sectors so that we can understand whether they differ.

Canada's total capital stock was roughly steady relative to output until the mid-1990s, after which it declined slightly. The drop was led by a relative decline in engineering construction, which stopped growing in the 1980s. The output-to-capital ratios of building construction remained roughly steady while that of machinery and equipment increased. In combination, the relative stability of total capital, along with increases in the shares of machinery and equipment and declines in engineering capital are consistent with changes in relative prices over time that have made the former relatively less expensive than the latter and led to substitution between different forms of assets. That this substitution also occurred in the United States indicates that similar forces were at work in the two economies.

The study also compared Canada's long-term infrastructure growth history with that of the United States. The period from 1960 to 2000 divides into two approximately equal periods. Prior to 1980, gross domestic product (GDP) and capital grew more quickly in Canada than in the United States. The relative performance in Canada slowed thereafter. But the slowdown in spending on structures was only part of the overall slowdown. Machinery and equipment in Canada slowed even more than did spending on structures.

Since changes at the level of the economy can hide differences within sectors, we also examined the changes that occurred within the public sector and certain other infrastructure industries. The decline in infrastructure capital relative to output is primarily due to developments in those sectors.

The relative decline in engineering construction in the aggregate economy is not, with the exception of the transportation sector, due to the relative decline in the importance of the goods and services that these sectors produce, but because almost all these sectors are using less engineering construction to produce their output. The within-sector decline could be due to one of three reasons. The first possibility is that these sectors have invested too little, and are producing higher output by working their infrastructure too hard, thus wearing it out. The second possibility is that firms have substituted other types of capital (i.e., machinery and equipment) and labour for infrastructure capital. The third possibility is that the firms in these sectors are making better use of their infrastructure capital. It could mean that these firms have found ways to better use their existing capital. Alternatively, they may in the past have built excess capacity in anticipation of higher future demand.

Since the downward trends in infrastructure-to-GDP ratios have persisted over a long period of time (almost 20 years) and are consistent across infrastructure sectors, the first possibility seems unlikely. Moreover, the Canadian trends were broadly duplicated in the United States. A more plausible explanation is that firms in these sectors have become more efficient in using their capital, either because they started from a position of over-capacity or because they have increased their productivity.

With regards to the public sector's infrastructure, its importance in the economy (infrastructure capital relative to total GDP) has been declining steadily since the early 1970s, in spite of the increase in the public sector's share of output until 1993. This trend can be found in both Canada and the United States. This is due to an increase in expenditures on labour in the public sector. In a sense, public administration is becoming more of a service sector and requires relatively less infrastructure capital and more labour services to produce the output that is being demanded of it.

While infrastructure capital has been declining, relative to other forms of capital, it has not declined in relative terms compared with the population that it is servicing. Indeed the amount of public sector infrastructure capital per capita has been relatively constant over the last 20 years.

In conclusion, infrastructure assets not only have characteristics that differentiate them from other types of capital, but their usage patterns distinguish them from other assets. They are highly concentrated in a small number of sectors that are either non-commercial or where there is regulation and substantial public ownership. Moreover, the growth pattern of these assets has followed quite a different trajectory than other assets over much of the last 40 years. Whether in the commercial or the public administration sector, these assets have grown considerably more slowly than other assets.

Appendix A

The Classification of the Functions of Government (COFOG) is a functional classification of government expenditure by purpose. It classifies government expenditures, including capital investment, by the areas to which they are intended to contribute.

The COFOG is divided into 10 two-digit divisions, which are sub-divided into three-digit groups, and then into four-digit categories classes. The divisions are general public services; defence; public order and safety; economic affairs; environmental protection; housing and community amenities; health; recreation, culture and religion; education; and social protection. The table below lists the divisions, groups and classes that are applicable to the assets we consider here.

It should be kept in mind that in some categories, the COFOG focuses on the role of government according to the purpose of an **industry**. We are focused on the purpose of the **asset**. That focus leads to problems for some assets which do not have a single purpose. The purpose of the asset in these cases may depend on the industry in which they are found. Although we could resort to industry characteristics to classify these assets, we choose not to deviate from our asset-focused criteria.

<table>
<tr><th>COFOG division</th><th colspan="2">COFOG group and class</th><th colspan="2">Assets (by type)</th></tr>
<tr><td>702 Defence</td><td colspan="2">7021 Military defence</td><td rowspan="2">Buildings</td><td>1214 Armouries, barracks, drill halls and other military-type structures</td></tr>
<tr><td>703 Public order and safety</td><td colspan="2">7032 Fire protection services
7034 Prisons</td><td>1209 Penitentiaries, detention centres and courthouses
1211 Fire stations, fire halls</td></tr>
<tr><td rowspan="9">704 Economic affairs</td><td rowspan="2">7042 Agriculture</td><td rowspan="2">70421 Agriculture</td><td>Engineering construction</td><td>2005 Irrigation and land reclamation projects</td></tr>
<tr><td>Buildings</td><td>1021 Farm buildings</td></tr>
<tr><td rowspan="7">7043 Fuel and energy
7045 Transport</td><td>70435 Electricity</td><td>Engineering construction</td><td>2401 Reservoirs (include dams)
2801 Electric power construction
2811 Production plant - steam
2812 Production plant - nuclear
2813 Production plant - hydraulic
2814 Overhead cables and lines (include poles, towers and all related parts and costs capitalized to this account) (transmission lines)
2815 Underground cables and lines (include trenching, tunnels and all related parts and costs capitalized to this account) (transmission lines)
2816 Overhead cables and lines (include poles, towers and all related parts and costs capitalized to this account) (distribution lines)
2817 Underground cables and lines (include trenching, tunnels and all related parts and costs capitalized to this account) (distribution lines)</td></tr>
<tr><td>70451 Road transport</td><td>Engineering construction</td><td>1017 Parking lots and parking garages
2202 Highways, roads, streets (include logging roads, signs, guardrails, lighting, landscaping, sidewalks, fences)</td></tr>
<tr><td>70452 Water transport</td><td>Engineering construction</td><td>2001 Docks, wharves, piers, terminals (e.g., coal, oil, natural gas, containers, general cargo)
2002 Dredging and pile driving
2003 Breakwaters
2004 Canals and waterways
2099 Other marine construction</td></tr>
<tr><td rowspan="2">70453 Rail transport</td><td>Engineering construction</td><td>2204 Rail track and roadbeds (include signals and interlockers)</td></tr>
<tr><td>Buildings</td><td>1009 Railway shops, engine houses</td></tr>
<tr><td rowspan="2">70454 Air transport</td><td>Engineering construction</td><td>2203 Runways (include lighting)</td></tr>
<tr><td>Buildings</td><td>1010 Aircraft hangars</td></tr>
</table>

<table>
<tr><th>COFOG division</th><th colspan="2">COFOG group and class</th><th colspan="2">Assets (by type)</th></tr>
<tr><td rowspan="5">704
Economic affairs</td><td rowspan="3">7043 Fuel and energy
7045 Transport</td><td rowspan="2">Other transport</td><td>Engineering construction</td><td>2205 Bridges, trestles, overpasses
2206 Tunnels
2299 Other transportation construction</td></tr>
<tr><td>Buildings</td><td>2201 Passenger terminals (e.g., air, boat, bus, rail and other)</td></tr>
<tr><td>70455 Pipeline transport</td><td>Engineering construction</td><td>3201 Gas mains and services
3202 Pumping stations, oil
3203 Pumping stations, gas
3205 Oil pipelines
3206 Gas pipelines</td></tr>
<tr><td rowspan="2">7046 Communication</td><td rowspan="2">70460 Communication</td><td>Engineering construction</td><td>3002 Cables and lines - coaxial, copper, aluminium, etc. (exclude optical fibre) (e.g., aerial, underground and submarine)
3003 Transmission support structures - towers, poles, conduit
3022 Optical fibre (e.g., aerial, underground and submarine)
3099 Other communication construction</td></tr>
<tr><td>Buildings</td><td>1212 Post offices
3001 Broadcasting and communication buildings[17]</td></tr>
<tr><td rowspan="3">705
Environmental protection
706
Housing and community amenities</td><td colspan="2">7051 Waste management</td><td>Buildings</td><td>1213 Waste disposal facilities</td></tr>
<tr><td colspan="2">7052 Waste water management
7063 Water supply</td><td rowspan="2">Engineering construction</td><td>2401 Reservoirs (include dams)
2402 Trunk and distribution mains
2412 Water pumping stations and filtration plants
2413 Water storage tanks
2499 Other waterworks construction
2601 Sewage treatment and disposal plants (include pumping stations)
2602 Sanitary and storm sewers, trunk and collection lines, open storm ditches
2603 Lagoons
2699 Other sewage system construction</td></tr>
<tr><td colspan="2">7053 Pollution abatement</td><td>1005 Pollution, abatement and control</td></tr>
<tr><td>707 Health</td><td colspan="2">7073 Hospital services</td><td>Buildings</td><td>1204 Hospitals, health centres, clinics and other health care centres (exclude residential construction)</td></tr>
</table>

17. Although many buildings in this category belong in the 70830 Broadcasting and publishing services group (part of 708 Recreation, culture and religion), telecommunications and broadcasting are aggregated into a single group in the XXXX dataset. Therefore, we list them all under communications, but note that some buildings may be misclassified.

COFOG division	COFOG group and class	Assets (by type)	
708 Recreation, culture and religion 709 Education	7081 Recreational and sporting services 7082 Cultural services 7091-7096 Education	Engineering construction	1020 Outdoor recreational facilities (e.g., parks, open stadiums, golf courses, ski resorts)
		Buildings	1018 Theatres, performing arts and cultural centres 1019 Indoor recreational buildings (e.g., sport complex, clubhouses, covered stadiums) 1201 Schools (include technical, vocational), colleges, universities and other educational buildings 1202 Student residences (exclude residential construction) 1207 Libraries 1208 Historical sites 1210 Museums, science centres, public archives
	70840 Religious and other community services		1203 Churches and other religious buildings
710 Social protection	71090 Social protection	Buildings	1206 Day-care centres 1205 Nursing homes, homes for the aged
7047 Other industries	70471 Distributive trades, storage and warehousing	Engineering construction	3204 Bulk storage
		Buildings	1006 Warehouses, refrigerated storage, freight terminals 1007 Grain elevators and terminals[18]
	70472 Hotels and restaurants		1014 Hotels, motels, convention centres
Unclassifiable		Engineering construction	1299 Other institutional and governmental construction 1999 Other building construction 2899 Other construction (not specified elsewhere) 3299 Other oil and gas facilities 4999 Other engineering construction 5999 Other construction
		Buildings	1097 Other industrial construction 1098 Other commercial construction
			1004 Laboratories, research and development centres 1008 Maintenance garages, workshops, equipment storage facilities 1013 Office buildings 1022 Bunkhouses, dormitories, camp cookeries, camps

18. Although this asset serves the agriculture industry, the function of the asset is one of storage. We thus include it as part of the distribution and storage group. It should be noted, however, the COFOG description of this group refers to the function of industries, rather than the assets, whereas our classification system refers to asset function only. This constitutes a minor discrepancy between our classification and COFOG.

The other assets fall in either the mining or manufacturing industries, which are assumed to be exclusively private. As such, their assets inhabit a different space in our classification system, although it cannot be ruled out with the available information that these assets may contain features of public infrastructure. Below is a list of these assets, and the COFOG categories in which they would appear if they were subject to government intervention.

COFOG division	COFOG group and class	Assets (by type)	
7043 Fuel and energy 7044 Mining, manufacturing and construction	70431 Coal and other solid mineral fuels 70441 Mining of mineral resources other that mineral fuels	Engineering construction	3216 Exploration drilling 3217 Development drilling 3218 Production facilities 3219 Enhanced recovery projects 3220 Drilling expenditures, pre-mining, research and all other costs 3221 Geological and geophysical expenditures 3401 Mine buildings, including headframes, ore bins, ventilation structures, backfill plants and other surface buildings 3402 Mine buildings for beneficiation treatment of minerals (excluding smelters and refineries) 3403 Mine shafts, drifts, crosscuts, raises, declines, sloping, etc. 3404 Tailing disposal system, settling ponds 3411 Mine site exploration 3412 Mine site development 3413 Exploration and deposit appraisal, off-mine sites expenditures
	70442 Manufacturing	Engineering construction	1002 Oil refineries 1003 Natural gas processing plants
		Buildings	1001 Plants for manufacturing
7047 Other industries	70471 Distributive trades and warehousing	Buildings	1011 Service stations (include self-serve and car washes) 1012 Automotive dealerships 1016 Shopping centres, plazas, malls, stores
	70472 Hotels and restaurants 70473 Tourism		1015 Restaurants, fast-food outlets, bars, nightclubs

Appendix B

Appendix B classifies assets by Classification of the Functions of Government (COFOG) division and industry recording the asset.

COFOG division	Assets (by type)		Industries recording assets
702 Defence	Buildings	1214 Armouries, barracks, drill halls and other military type structures	91 Public administration
703 Public order and safety	Buildings	1209 Penitentiaries, detention centres and courthouses	91 Public administration
703 Public order and safety	Buildings	1211 Fire stations, fire halls	91 Public administration 53 Real estate and rental and leasing
704 Economic affairs	Engineering construction	2005 Irrigation and land reclamation projects	91 Public administration 11 Agriculture, forestry, fishing and hunting 54 Professional, scientific and technical services
704 Economic affairs	Buildings	1021 Farm buildings	11 Agriculture, forestry, fishing and hunting 54 Professional, scientific and technical services 71 Arts, entertainment and recreation
704 Economic affairs	Engineering construction	2801 Electric power construction	91 Public administration 2211 Electric power generation, transmission and distribution 21 Mining and oil and gas extraction 31-33 Manufacturing
704 Economic affairs	Engineering construction	2401 Reservoirs (include dams) 2811 Production plant - steam 2812 Production plant - nuclear 2813 Production plant - hydraulic 2814 Overhead cables and lines (include poles, towers and all related parts and costs capitalized to this account) (transmission lines) 2815 Underground cables and lines (include trenching, tunnels and all related parts and costs capitalized to this account) (transmission lines) 2816 Overhead cables and lines (include poles, towers and all related parts and costs capitalized to this account) (distribution lines) 2817 Underground cables and lines (include trenching, tunnels and all related parts and costs capitalized to this account) (distribution lines)	2211 Electric power generation, transmission and distribution

COFOG division	Assets (by type)		Industries recording assets
704 Economic affairs	Engineering construction	1017 Parking lots and parking garages	21 Mining and oil and gas extraction 23 Construction 31-33 Manufacturing 41 Wholesale trade 44-45 Retail trade 48-49 Transportation and warehousing 481 Air transportation 482 Rail transportation 483 Water transportation 484 Truck transportation 485 Transit and ground passenger transportation 487 Scenic and sightseeing transportation 488 Support activities for transportation 491 Postal service 492 Couriers and messengers 493 Warehousing and storage 53 Real estate and rental and leasing 561 Administrative and support services 81 Other services (except public administration) 91 Public administration
		2202 Highways, roads, streets (include logging roads, signs, guardrails, lighting, landscaping, sidewalk, fences)	91 Public administration 2211 Electric power generation, transmission and distribution 21 Mining and oil and gas extraction 31-33 Manufacturing 44-45 Retail trade 561 Administrative and support services 482 Rail transportation 485 Transit and ground passenger transportation 487 Scenic and sightseeing transportation 488 Support activities for transportation 486 Pipeline transportation
		2001 Docks, wharves, piers, terminals (e.g., coal, oil, natural gas, containers, general cargo)	21 Mining and oil and gas extraction 31-33 Manufacturing 483 Water transportation 486 Pipeline transportation 487 Scenic and sightseeing transportation 488 Support activities for transportation
		2002 Dredging and pile driving	91 Public administration 11 Agriculture, forestry, fishing and hunting 487 Scenic and sightseeing transportation 488 Support activities for transportation

COFOG division	Assets (by type)		Industries recording assets
704 Economic affairs	Engineering construction	2003 Breakwaters	91 Public administration
		2004 Canals and waterways	91 Public administration 487 Scenic and sightseeing transportation 488 Support activities for transportation
		2099 Other marine construction	91 Public administration 21 Mining and oil and gas extraction 487 Scenic and sightseeing transportation 488 Support activities for transportation
		2204 Rail track and roadbeds (include signals and interlockers)	21 Mining and oil and gas extraction 31-33 Manufacturing 482 Rail transportation 485 Transit and ground passenger transportation 487 Scenic and sightseeing transportation 488 Support activities for transportation 91 Public administration
	Buildings	1009 Railway shops, engine houses	482 Rail transportation 485 Transit and ground passenger transportation 487 Scenic and sightseeing transportation 488 Support activities for transportation
	Engineering construction	2203 Runways (include lighting)	481 Air transportation 487 Scenic and sightseeing transportation 488 Support activities for transportation 91 Public administration
	Buildings	1010 Aircraft hangars	
	Engineering construction	2205 Bridges, trestles, overpasses	11 Agriculture, forestry, fishing and hunting 482 Rail transportation 485 Transit and ground passenger transportation 487 Scenic and sightseeing transportation 488 Support activities for transportation 91 Public administration
		2206 Tunnels	482 Rail transportation 485 Transit and ground passenger transportation 487 Scenic and sightseeing transportation 488 Support activities for transportation

COFOG division	Assets (by type)		Industries recording assets
704 Economic affairs	Engineering construction	2299 Other transportation construction	31-33 Manufacturing 44-45 Retail trade 482 Rail transportation 485 Transit and ground passenger transportation 487 Scenic and sightseeing transportation 488 Support activities for transportation
	Buildings	2201 Passenger terminals (e.g., air, boat, bus, rail and other)	481 Air transportation 482 Rail transportation 483 Water transportation 485 Transit and ground passenger transportation 487 Scenic and sightseeing transportation 488 Support activities for transportation 53 Real estate and rental and leasing 561 Administrative and support services 91 Public administration
	Engineering construction	3201 Gas mains and services	2212 Natural gas distribution 31-33 Manufacturing 486 Pipeline transportation 91 Public administration
		3202 Pumping stations, oil	486 Pipeline transportation
		3203 Pumping stations, gas	2212 Natural gas distribution 486 Pipeline transportation
		3205 Oil pipelines	31-33 Manufacturing 41 Wholesale trade 486 Pipeline transportation
		3206 Gas pipelines	31-33 Manufacturing 2212 Natural gas distribution 486 Pipeline transportation
		3002 Cables and lines - coaxial, copper, aluminium, etc. (exclude optical fibre) (e.g., aerial, underground and submarine)	31-33 Manufacturing 485 Transit and ground passenger transportation 511 Publishing industries (except Internet) 512 Motion picture and sound recording industries 515 Broadcasting (except Internet) 517 Telecommunications

COFOG division	Assets (by type)		Industries recording assets
704 Economic affairs	Engineering construction	3003 Transmission support structures - towers, poles, conduits	482 Rail transportation 485 Transit and ground passenger transportation 486 Pipeline transportation 487 Scenic and sightseeing transportation 488 Support activities for transportation 511 Publishing industries (except Internet) 512 Motion picture and sound recording industries 515 Broadcasting (except Internet) 517 Telecommunications 91 Public administration
		3022 Optical fibre (e.g., aerial, underground and submarine)	515 Broadcasting (except Internet) 517 Telecommunications
		3099 Other communication construction	485 Transit and ground passenger transportation 511 Publishing industries (except Internet) 512 Motion picture and sound recording industries 515 Broadcasting (except Internet) 517 Telecommunications 91 Public administration
	Buildings	1212 Post offices	491 Postal service 492 Couriers and messengers
		3001 Broadcasting and communication buildings[19]	511 Publishing industries (except Internet) 512 Motion picture and sound recording industries 515 Broadcasting (except Internet) 517 Telecommunications 518 Internet service providers, web search portals, data processing services 81 Other services (except public administration) 91 Public administration
705 Environmental protection 706 Housing and community amenities	Engineering construction	1213 Waste disposal facilities	2211 Electric power generation, transmission and distribution 31-33 Manufacturing 562 Waste management and remediation services 91 Public administration

19. Although many buildings in this category belong in the 70830 Broadcasting and publishing services group (part of 708 Recreation, culture and religion), telecommunications and broadcasting are aggregated into a single group in the XXXX dataset. Therefore, we list them all under communications, but note that some buildings may be misclassified.

COFOG division	Assets (by type)		Industries recording assets
705 Environmental protection 706 Housing and community amenities	Engineering construction	2401 Reservoirs (include dams)	2213 Water, sewage and other systems 31-33 Manufacturing 562 Waste management and remediation services 91 Public administration
		2402 Trunk and distribution mains	11 Agriculture, forestry, fishing and hunting 21 Mining and oil and gas extraction 2213 Water, sewage and other systems 31-33 Manufacturing 562 Waste management and remediation services
		2412 Water pumping stations and filtration plants 2413 Water storage tanks	21 Mining and oil and gas extraction 2213 Water, sewage and other systems
		2499 Other waterworks construction 2601 Sewage treatment and disposal plants (include pumping stations)	21 Mining and oil and gas extraction 31-33 Manufacturing 2213 Water, sewage and other systems 91 Public administration
		2602 Sanitary and storm sewers, trunk and collection lines, open storm ditches	21 Mining and oil and gas extraction 31-33 Manufacturing 91 Public administration
		2603 Lagoons 2699 Other sewage system construction	31-33 Manufacturing 91 Public administration
		1005 Pollution, abatement and control	11 Agriculture, forestry, fishing and hunting 21 Mining and oil and gas extraction 2211 Electric power generation, transmission and distribution 2213 Water, sewage and other systems 31-33 Manufacturing 562 Waste management and remediation services 91 Public administration
707 Health	Buildings	1204 Hospitals, health centres, clinics and other health care centres (exclude residential construction)	52 Finance and insurance 53 Real estate and rental and leasing 91 Public administration
708 Recreation, culture and religion 709 Education	Engineering construction	1020 Outdoor recreational facilities (e.g. parks, open stadiums, golf courses, ski resorts)	53 Real estate and rental and leasing 91 Public administration
	Buildings	1018 Theatres, performing arts and cultural centres	512 Motion picture and sound recording industries 52 Finance and insurance 53 Real estate and rental and leasing 71 Arts, entertainment and recreation 91 Public administration
		1019 Indoor recreational buildings (e.g., sport complexes, clubhouses, covered stadiums)	512 Motion picture and sound recording industries 53 Real estate and rental and leasing 71 Arts, entertainment and recreation 91 Public administration
		1201 Schools (include technical, vocational), colleges, universities and other educational buildings	53 Real estate and rental and leasing 71 Arts, entertainment and recreation 81 Other services (except public administration) 91 Public administration

COFOG division	Assets (by type)		Industries recording assets
708 Recreation, culture and religion 709 Education	Buildings	1202 Student residences (exclude residential construction) 1207 Libraries 1208 Historical sites	91 Public administration
		1210 Museums, science centres, public archives	512 Motion picture and sound recording industries 53 Real estate and rental and leasing 71 Arts, entertainment and recreation 81 Other services (except public administration) 91 Public administration
		1203 Churches and other religious buildings	52 Finance and insurance 53 Real estate and rental and leasing 81 Other services (except public administration)
710 Social protection	Buildings	1205 Nursing homes, homes for the aged	53 Real estate and rental and leasing 91 Public administration
		1206 Day care centres	91 Public administration
7047 Other industries	Engineering construction	3204 Bulk storage	11 Agriculture, forestry, fishing and hunting 31-33 Manufacturing 2211 Electric power generation, transmission and distribution 2212 Natural gas distribution 41 Wholesale trade 44-45 Retail trade 481 Air transportation 485 Transit and ground passenger transportation 486 Pipeline transportation 487 Scenic and sightseeing transportation 488 Support activities for transportation 493 Warehousing and storage 512 Motion picture and sound recording industries 81 Other services (except public administration) 91 Public administration

COFOG division	Assets (by type)		Industries recording assets
7047 Other industries	Buildings	1006 Warehouses, refrigerated storage, freight terminals	11 Agriculture, forestry, fishing and hunting 21 Mining and oil and gas extraction 31-33 Manufacturing 2211 Electric power generation, transmission and distribution 2212 Natural gas distribution 41 Wholesale trade 44-45 Retail trade 481 Air transportation 482 Rail transportation 483 Water transportation 484 Truck transportation 485 Transit and ground passenger transportation 486 Pipeline transportation 487 Scenic and sightseeing transportation 488 Support activities for transportation 491 Postal service 492 Couriers and messengers 493 Warehousing and storage 52 Finance and insurance 53 Real estate and rental and leasing 54 Professional, scientific and technical services 561 Administrative and support services 562 Waste management and remediation services 91 Public administration
		1007 Grain elevators and terminals[20]	31-33 Manufacturing 41 Wholesale trade 493 Warehousing and storage
		1014 Hotels, motels, convention centres	31-33 Manufacturing 53 Real estate and rental and leasing 71 Arts, entertainment and recreation 72 Accommodation and food services 81 Other services (except public administration) 91 Public administration
Unclassifiable	Engineering construction	1299 Other institutional and governmental construction	31-33 Manufacturing 512 Motion picture and sound recording industries 53 Real estate and rental and leasing 71 Arts, entertainment and recreation 81 Other services (except public administration) 91 Public administration
		1999 Other building construction	91 Public administration
		2899 Other construction (not specified elsewhere)	2211 Electric power generation, transmission and distribution

20. Although this asset serves the agriculture industry, the function of the asset is one of storage. We thus include it as part of the distribution and storage group. It should be noted, however, the COFOG description of this group refers to the function of industries, rather than the assets, whereas our classification system refers to asset function only. This constitutes a minor discrepancy between our classification and COFOG.

COFOG division	Assets (by type)		Industries recording assets
Unclassifiable	Engineering construction	3299 Other oil and gas facilities	21 Mining and oil and gas extraction 2212 Natural gas distribution 31-33 Manufacturing 44-45 Retail trade 486 Pipeline transportation
		4999 Other engineering construction	2213 Water, sewage and other systems 31-33 Manufacturing 91 Public administration
		5999 Other construction	21 Mining and oil and gas extraction 31-33 Manufacturing 41 Wholesale trade 44-45 Retail trade 487 Scenic and sightseeing transportation 488 Support activities for transportation 53 Real estate and rental and leasing 54 Professional, scientific and technical services 81 Other services (except public administration) 91 Public administration
	Buildings	1097 Other industrial construction	11 Agriculture, forestry, fishing and hunting 21 Mining and oil and gas extraction 2211 Electric power generation, transmission and distribution 2212 Natural gas distribution 2213 Water, sewage and other systems 31-33 Manufacturing 487 Scenic and sightseeing transportation 488 Support activities for transportation 493 Warehousing and storage
		1098 Other commercial construction	41 Wholesale trade 44-45 Retail trade 512 Motion picture and sound recording industries 515 Broadcasting (except Internet) 517 Telecommunications 52 Finance and insurance 53 Real estate and rental and leasing 54 Professional, scientific and technical services 561 Administrative and support services 562 Waste management and remediation services 71 Arts, entertainment and recreation 81 Other services (except public administration) 91 Public administration

COFOG division	Assets (by type)		Industries recording assets
Unclassifiable	Buildings	1004 Laboratories, research and development centres	21 Mining and oil and gas extraction 2211 Electric power generation, transmission and distribution 31-33 Manufacturing 511 Publishing industries (except Internet) 518 Internet service providers, web search portals, and data processing services 52 Finance and insurance 53 Real estate and rental and leasing 54 Professional, scientific and technical services 561 Administrative and support services 91 Public administration
		1008 Maintenance garages, workshops, equipment storage facilities	11 Agriculture, forestry, fishing and hunting 21 Mining and oil and gas extraction 2211 Electric power generation, transmission and distribution 2212 Natural gas distribution 2213 Water, sewage and other systems 31-33 Manufacturing 41 Wholesale trade 44-45 Retail trade 481 Air transportation 482 Rail transportation 483 Water transportation 484 Truck transportation 485 Transit and ground passenger transportation 486 Pipeline transportation 487 Scenic and sightseeing transportation 488 Support activities for transportation 491 Postal service 492 Couriers and messengers 493 Warehousing and storage 512 Motion picture and sound recording industries 515 Broadcasting (except Internet) 517 Telecommunications 52 Finance and insurance 53 Real estate and rental and leasing 561 Administrative and support services 562 Waste management and remediation services 71 Arts, entertainment and recreation 81 Other services (except public administration) 91 Public administration

COFOG division	Assets (by type)		Industries recording assets
Unclassifiable	Buildings	1013 Office buildings	11 Agriculture, forestry, fishing and hunting 21 Mining and oil and gas extraction 2211 Electric power generation, transmission and distribution 2212 Natural gas distribution 2213 Water, sewage and other systems 23 Construction 31-33 Manufacturing 41 Wholesale trade 44-45 Retail trade 481 Air transportation 482 Rail transportation 483 Water transportation 484 Truck transportation 485 Transit and ground passenger transportation 486 Pipeline transportation 487 Scenic and sightseeing transportation 488 Support activities for transportation 491 Postal service 492 Couriers and messengers 493 Warehousing and storage 511 Publishing industries (except Internet) 518 Internet service providers, web search portals, and data processing services 512 Motion picture and sound recording industries 515 Broadcasting (except Internet) 517 Telecommunications 52 Finance and insurance 53 Real estate and rental and leasing 561 Administrative and support services 562 Waste management and remediation services 71 Arts, entertainment and recreation 72 Accommodation and food services 81 Other services (except public administration) 91 Public administration
		1022 Bunkhouses, dormitories, camp cookeries, camps	21 Mining and oil and gas extraction 71 Arts, entertainment and recreation 72 Accommodation and food services

The other assets fall in either the mining or manufacturing industries, which are assumed to be exclusively private. As such, their assets inhabit a different space in our classification system, although it cannot be ruled out with the available information that these assets may contain features of public infrastructure. Below is a list of these assets, and the COFOG categories in which they would appear if they were subject to government intervention.

COFOG division	Assets (by type)		Industries recording assets
7043 Fuel and energy 7044 Mining, manufacturing and construction	Engineering construction	3216 Exploration drilling 3217 Development drilling 3218 Production facilities 3219 Enhanced recovery projects 3220 Drilling expenditures, pre-mining, research and all other costs 3221 Geological and geophysical expenditures 3401 Mine buildings including headframes, ore bins, ventilation structures, backfill plants and other surface buildings 3402 Mine buildings for beneficiation treatment of minerals (excluding smelters and refineries) 3403 Mine shafts, drifts, crosscuts, raises, declines, sloping, etc 3404 Tailing disposal system, settling ponds 3411 Mine site exploration 3412 Mine site development 3413 Exploration and deposit appraisal, off mine sites expenditures	21 Mining and oil and gas extraction
		1002 Oil refineries 1003 Natural gas processing plants	31-33 Manufacturing
	Buildings	1001 Plants for manufacturing	11 Agriculture, forestry, fishing and hunting 21 Mining and oil and gas extraction 31-33 Manufacturing 511 Publishing industries (except Internet) 52 Finance and insurance 53 Real estate and rental and leasing 81 Other services (except public administration)
7047 Other industries	Buildings	1011 Service stations (include self-serve and car washes)	41 Wholesale trade 44-45 Retail trade 81 Other services (except public administration)
		1012 Automotive dealerships	41 Wholesale trade 44-45 Retail trade 52 Finance and insurance 53 Real estate and rental and leasing
		1016 Shopping centres, plazas, malls, stores	31-33 Manufacturing 41 Wholesale trade 44-45 Retail trade 52 Finance and insurance 53 Real estate and rental and leasing 54 Professional, scientific and technical services 561 Administrative and support services 71 Arts, entertainment and recreation 72 Accommodation and food services
		1015 Restaurants, fast-food outlets, bars, nightclubs	71 Arts, entertainment and recreation 72 Accommodation and food services

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