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The impact of infrastructure on productivity: new estimates for Québec

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Abstract:

Since the works of Aschauer (1989a) and Munnell (1990), several authors have attempted to establish a relationship between public infrastructure spending and productivity or economic growth. In this paper, we use the dual approach to model the contribution of public spending in infrastructure in the province of Quebec, which is the same approach that was proposed by Harchaoui and Tarkhani (2003) and applied to the Canadian economy. We use Quebec economy data to measure the contribution of public capital to sectoral economic growth for the 1997-2002 period. Our results confirm a positive relationship between public capital and economic growth albeit of smaller magnitude than those estimated in Harchaoui and Tarkhani (2003).

KeyWords: Infrastructure, investment, growth, productivity

JEL codes: C13, D62, E22, H41, H54

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1. Introduction

For the last two decades, the interest around the productive aspect of public capital (e.g. roads, highways, etc) has considerably soared thanks to the publication of theoretical papers on growth and numerous empirical studies on the matter. Whereas Barro (1990) presented an endogenous growth model with productive public expenditures, Aschauer (1989a) offered a thoroughly different proposal on the issue that would be the source of debates for years to come.

Barro (1990) showed that productive public expenditures assimilated to public capital can play a key role in a self-sustained economic growth process. He paved the way to a series of theoretical contributions aiming at establishing the impact of public infrastructure on productivity and long-run economic growth in the context of endogenous growth. Nowadays if a relative consensus exists amongst economists about the relevance to consider the public capital stock in the analysis of the production process, it does not necessarily hold true with regard to the empirical validation of these effects.

This paper aims to estimate the contribution of public capital to sectoral growth for the Quebec economy. The estimation of the contribution of public capital will allow us to verify if the results are similar to those obtained for Canada and to shed light on the magnitude of the impact of productive infrastructure in this Canadian province. This bears a particular interest considering that the provincial government has considerably invested in the infrastructure network in recent years with an average of $9 billion a year between 2007-2008 and 2014-2015. This is a threefold increase compared to the average between 2001 and 2006. Moreover, the projected expenditures in infrastructure is expected to remain high as the *Programme Québécois des Infrastructure (2015-2025)* outlines an average annual investment of $9,1 billion until 2019-2020 and $8,6 billion between 2020-2025.

In the first section, we present a literature review of the different estimation methods used to measure the impact of public capital on growth. This section includes a discussion on the different issues related to the definition of public capital, the primal, the dual, and the non-parametric estimations methods. In the subsequent section, we describe the methodology we used to estimate the coefficients and the following sections include a discussion of the results obtained and potential implications the provincial economy.

2. Literature review

2.1. Public capital definition

Assessing the contribution of public capital to gross domestic product (GDP) involves several challenges, the first being a proper specification of what constitutes public capital. From the outset, defining public capital only according to the proprietorship inexorably leads to an amalgam of infrastructure of various levels of productivity. For example, it seems improbable that a newly built highway induces the same change in productivity as a museum. Gramlich (1994) believes that the confusion surrounding the definitions of public capital and infrastructure capital originates from defining them in regards to their ownership. Bom and Ligthard (2009) define public capital as being comprised of an infrastructure core including roads, highways, airports and public services such as sewers, hospitals, the schooling network, and other public buildings. The authors argue that such an infrastructure core should be considered productive[1].

Beside the problem inherent to the definition and what constitutes public capital, the consolidation level or the disaggregation of public capital stocks is another issue. These elements contribute to the relative lack of consensus surrounding the productivity role of public capital. Some authors like Aschauer (1989a) and Harchaoui and Tarkhani (2003) use public capital stocks aggregated at the national level, which has an impacts on the implications that their results might have on public policy. Some regions can have a public capital stock closer to the optimum and needless to say that the marginal benefit of a new investment in such a region could be significantly different than it would be in other regions where the public capital stock is farther from equilibrium. Prud'homme (1996) incorporates this dimension in a model for France where he estimates the regional public and private capital stocks as well as the labor supply for twenty regions. He concludes that the density of the capital stock of each region depending on the size of the area served by the capital stock is an important explanatory factor of regional disparities in terms of productivity of public capital.

The economic literature provides heterogeneous definitions of public capital that can explain great disparities in findings of empirical test of this relationship. However, it seems reasonable to limit the analysis of public capital to infrastructures bearing a sizable productivity component such as the aforementioned infrastructure core.

2.2. Issues surrounding public capital

The existence and the magnitude of the positive externalities associated to public capital are of considerable importance for public policy. Given the contribution of public capital to growth, investing in infrastructures has become a macroeconomic management tool especially in periods of slow growth or recession. Moreover, some argue that investing in infrastructures might be an efficient remedy to counter the Dutch disease, which occurs when a substantial growth in an exporting industry, such as the natural resources sector, induces a real exchange rate increase (Adam and Bevan, 2006). This

[1] The authors use the estimates of Aschauer (1989a) for the period 1949-1985.

real exchange rate increase reduces the competitiveness of all exporting firms, which negatively impacts the production level of the rest of the economy.

The direct production externality that we described is not the only externality that public capital creates. While transport infrastructure spending might influence firms productivity, it could also impact the labour supply through their interaction with congestion face by users of the road network. An efficient road system contributes to the market efficiency and decreases transportation costs. Moreover, congestion costs, including wasted time in traffic, fuel and stress, can be considerable. Frank and Sumpf (1997) estimate that congestion costs Germany up to $100 billion/year. In order to reduce congestion costs, the government can spend to improve its road network leading to an increase in firm's productivity. Conrad and Heng (2007) show that an increase in infrastructure spending of €7,5 billion, financed through a tax on fuel, generates €15,5 billion over a 10-year period in gains.

However, the interaction between public capital and the economy goes beyond the externalities that we just described. There is a substantial debate over the relationship between private capital and public capital, including the role that public capital plays in the investment decisions taken by the private sector. In a full-employment context, the neoclassical approach assumes that public infrastructure spending that translates into a higher fiscal burden or an increase in public debt will increase the demand for goods and services, which will in turn reduce savings, increase the interest rate, and thus crowd-out private investment (Ahmed and Miller, 2000). However, this crowding-out effect is contested by numerous authors among which Berg el al (2007), Li and Rowe (2007), Mongardini and Rayner (2009). According to the Keynesian approach, when resources are not fully allocated, an increase in the public infrastructure investment will not crowd-out private investments but rather have a complementary effect on the latter. Thus, the private investment demand should increase thanks to improvements in the marginal productivity of private capital caused by public investments (Dumont and Mesplé-Somps, 2000). Faini (1994) tested this assumption empirically for 15 countries over the 1980 to 1990 period and concludes to the existence of a complementary effect between private en public investments.

Moreover, the creation of new infrastructures implies an additional maintenance and operating cost for the government. In order to quantify the extent of these costs, Fay and Yepes (2003) assess the infrastructure requirement and the associated maintenance and operating costs for 113 countries for the 2000 to 2010 period. They find that the new infrastructures impose an average operating and maintenance cost equivalent to 2.7% of GDP for these countries. Therefore, the choice of the financing method as well as the associated operating and maintenance costs of a new infrastructure should be taken into account since they have an effect on the economy for a much longer period than the period at which the initial investment is made.

The challenges and issues surrounding public capital demand require an appropriate specification in a modeling context. The links and interactions between public capital and the rest of the economy should be appropriately modeled for impact analysis. .

3. Estimation of elasticity coefficients

3.1. Primal form

The productive component of public spending has already been modeled through a primal form, namely via the production function. Barro (1990) developed a model in which national income depends on capital intensity and public spending. In his model, the public spending is completely financed through taxes, the optimum level of public spending is attained when the tax rate induced by the chosen public spending level equals the productivity rate of these spending. Hurlin (1999) highlights a limitation of such a modeling assumption since it does not integrate a dimension of capital stock. He also suggests that it is reasonable to think that the productivity effects are not so much the result of a flow of investment expenditure but rather the effect produced by the accumulated capital stock.

On the other hand, Aschauer (1989a) proposed a production function that includes the public capital stock (eq.1).

$$(1)\ Y_t = A_t * f(N_t, K_t, G_t)$$

where, Y_t is the output, (A_t) a measure of productivity, (N_t) aggregate labour supply, (K_t) the aggregate stock of non-residential capital, and (G_t) the public capital stock. Assuming a Cobb-Douglas production function and the logarithmic transformation for the estimation of coefficients *a*, *b* and *c* of the equation 2. These coefficients represent the elasticity of production with respect to the different inputs: private capital, labour and public capital.

$$(2)\ \ln Y_t = \ln A_t + a * \ln N_t + b * \ln K_t + c * \ln G_t$$

Aschauer (1989a) shows that public capital expenditures have a greater impact on GDP compared to other variables with an elasticity of 0.39. Not surprisingly, such a high value for the elasticity raised criticisms. Munnell (1992) underlines that it is unlikely that the contribution to growth is highest for public capital. According to her, the fact that public capital could have a higher impact on output than private capital is baffling when one takes into account that many benefits of public investments are not captured in the GDP. She conducted her own estimates of the contribution of public capital to the United States national output and finds a much lower but still positive elasticity of output with respect to public capital at 0.15. Although Munnell (1990) reproduces the methodology used by

Aschauer (1989a) by using public capital as an input in the firm's production function, the time period is different. Munnell (1990) selected the 1970-1986 period whereas Aschauer (1989a) chose a much longer period, covering more than 35 years, from 1949 to 1985. Incidentally, Munnell (1990) excluded the after-war period characterised by strong growth, in part due to the technological progress catch-up, the Marshall Plan, and the relatively uncontrolled inflation levels. The exclusion of this period provides greater consistency between the data analyzed and contemporary application of the results of these estimates. The difference in the period used may well be the source of the discrepancy between the two studies. Munnell (1990) also estimates this productive elasticity on GDP assuming there is a crowding out effect between public capital and private capital, which induces higher elasticities of between 0.33 and 0.41. We present a synthesis of the results of the main studies conducted in the 1990s (**Table 1**). The main feature of these results is the wide range in estimated values for parameters.

Table 1 ; Estimates of the elasticity of output with respect to the infrastructure stock

Study	Country	Level of Analysis	Type of infrastructure	Elasticity of Y with respect to infrastructure
Aschauer (1989b)	USA	National	Public capital	0,39 to 0,56
Munnell (1990)	USA	National	Public capital	0,33 to 0,41
Munnell and Cook (1990)	USA	State	Road infrastructure	0,15
Hulten and Schwabb (1991)	USA		Public capital	0,02 to 0,42**
Tatom (1991)	USA	State	Public capital	0,15*
Garcia-Mila and McGuire (1992)	USA	State	Road infrastructure*	0,04
Khanam (1996)	Canada	National	Road infrastructure	0,24 à 0,46
Khanam (1996)	Canada	Province	Road infrastructure	0,08 à 0,12

* Highways
**Relationship statistically non-significant
*** Coefficient statistically non-significant

Most studies find a positive elasticity for public capital in relation to output. However, Hulten and Schwabb (1991) do not find a statistically significant relationship between productivity growth and the growth of the public capital stock. Similarly, Tatom (1991) gets statistically insignificant coefficients because of the non-stationarity of the variables. Besides, Tatom (1991) criticizes the methodology used by Aschauer (1989a) and Munnell (1990), and highlight three main critics with regard to their results. First, the exclusion of certain variables such as energy prices can lead to a bias toward the reduction in productivity of the energy sector instead of a decline in growth of public capital productivity. Second, the omitted variables do not include time trends. These time trends were supposed to control for technological changes, which might bias the values of the estimated coefficients, especially those that could be correlated with an omitted variable. Finally, the author suggests that some variables are non-stationary, which could distort the estimates. Tatom (1991) as well as Berndt and Hansson (1992) also highlight simultaneity issues with the primal approach used by Aschauer (1989a) and Munnell (1990).

Garcia-Mila and Mcguire (1992) include inputs such as education and highways in the production function. The authors find that using highways as an approximation of the capital stock results in considerably lower elasticities with 0.04 and 0.045 depending on the regression performed. Overall, most studies using the primal approach confirm the positive contribution of public capital to GDP, although the estimated elasticities vary greatly. Although other estimation methods correct some of the problems linked with the primal approach, its main advantage resides in the limited data requirement for the application of the production function method.

3.2. The dual approach

Whereas the primal approach allows estimating solely the production function in order to analyse the relationship between public capital and national output, the dual approach integrates the estimation of the firm's cost function. Since input prices are dependent variables in the firm's cost function, they are more likely to be exogenous than the variables used to define the production function. According to McDonald (2008), using the cost function to estimate the relationship between capital and output is more appropriate. This relies on the fact that productivity increases because of its impacts on production factors. The dual approach proposes to go from the production structure to a constrained cost function, which can be estimated if input prices are available regarding. Thus, considering a production function similar to equation (1) and a cost function such as

(3) $C = f(w, Y, G)$

where w is a factor price vector, Y is the output, and G is the public capital. It is then possible to deduce an optimal cost function by minimizing this cost function. Since the productivity component of public infrastructures modifies the unit cost to produce and subsequently the production itself, it is possible to obtain the input demand functions by estimating the cost function. The dual approach allows capturing the eviction effect or the complementary effect between private and public capital. Variations in input demands, especially in the demand for private capital, will allow concluding to the existence or not of a complementary or substitution effect between the two variables.

When the dual approach also includes the estimation of the demand function of the firm, it is possible to estimate the multifactor productivity (MFP). This represents the part of the productivity that is not explained by input productivity (Gu and McDonald, 2009). It is measured by the difference between the growth of production and increase of the output that would have been observed following the increase of an amount of input (Baldwin and Wu, 2009).Thus,

$$(4) \qquad MFP = \Delta Y - \Delta Y_e = \Delta Y - F(\Delta I)$$

where Y is again the output, Y_e the predicted output and ΔI the change in the quantity of input.[2] Nonetheless, McDonald (2008) highlights an issue with a regression that includes both the MFP and public capital. He states that since growth of these two variables is highly similar, it might result in a multicolinearity bias.

Lynde and Richmond (1993) use a dual approach on American data over the 1958 to 1989 period. There results suggest that public capital impacts on productivity. They estimate the portion of the slowdown in the mid-1970s to the late 1980s due to the declining ratio of public capital over labor to 40%.

Nadiri and Manumeas (1994) use a panel of 12 American manufacturing industries and data from 1956 to 1986. With the dual approach, they conclude to a positive contribution of public infrastructures and the research and development (R&D) financed by the government to the total productivity of factors. Moreover, they find that the role of public infrastructures is significantly more important than the R&D. However, these results vary considerably depending on the sector considered. The contribution of infrastructure to productivity resides more specifically in the reduction in private costs, which points to the interest of using the dual approach.

Harchaoui and Tarkhani (2003) draw from Nadiri and Mamuneas (1994) and consider 37 sectors of the Canadian economy over the period 1961 to 2000. They find that the marginal benefits are positive across all sectors. These marginal benefits are considerable, being estimated to be on average 0.17$ per dollar increase in the net value of the public capital stock. Furthermore, the aggregated contribution of public capital to the growth of the MFP is estimated to be 18%. Similarly to Nidiri and Manumeas (1994), the increase in the observed productivity is explained by lower costs generated by public capital. It should be highlighted that elasticities vary considerably across sectors. Thus, elasticities of the construction, transport, wholesale and retail, and the communications industry are in the range of 0.19 to 0.42, which is in line with expectations since these industries use more public infrastructures than others, which subsequently allows them to benefit more from public infrastructure expenditure.

3.3. Non-parametric approach

While the primal approach generally relies on the estimation of a parametric function, its main advantage is that only data on inputs and outputs are required for estimation. On its part, the dual approach is based on the estimation of a parametric cost function. Although the dual method allows considering endogeneity of inputs, it also requires accurate information input prices data, which greatly limits the scope for applications given the difficulty in obtaining such data. The non- parametric method has the advantage of taking into consideration non linearity and there is no need to specify a

[2] For more details, see Baldwin and Wu (2009) pp. 11-14.

functional form. Henderson and Kumbhaka (2005) use the generalized kernel estimation method of Li and Racine (2004) to estimate the contributions of employment, private capital and public capital to the US production for forty-eight US states over a period of seventeen years. The main finding of Henderson and Kumbhaka (2005) is that the usual parametric specifications of the production function, namely the Cobb -Douglas and the translog function, are not supported by aggregate data at the state level. They explain this result by the inability of these functional forms to capture the non-linearity in the technology implicit of the functional form selected. They conclude to a significant contribution of public and private capital to production.

Gu and McDonald (2009) also use a non-parametric approach to estimate productivity by establishing an accounting framework for growth. The contribution of public capital to MFP has been isolated and is given by equation (5),

$$(5) \qquad \Delta \ln MFP_t^* = -\beta_K \Delta \ln L_t - \Delta \ln Y_t - \beta_L \Delta \ln L_t - \beta_G \Delta \ln G_t$$

where L_t, Y_t and G_t are respectively labour, GDP, and government expenditures.

Usually, the public capital impact is included in multifactor productivity (MFP), but as highlighted by the authors, historical variations of the MFP ought not to be exclusively explained by public capital variations. Estimating equation (5) leads to the conclusion that the contribution of public capital to the MFP growth has considerably varied in Canada between the 1960s and the beginning of the new millennium as its contribution was greater in the 60s and 70s than in the following decades.

4. Methodology

To estimate the contribution of infrastructures to productivity on the different industries of the Quebec economy, we chose the analytical framework used by Harchaoui and Tarkhani (2003). This is an example of the dual approach allowing for the estimation of the demand and cost functions as well as the MFP. The MFP requires estimating the demand and cost functions by industries. Through the analysis of the MFP for each branch, we can determine the significance of the contribution of public capital to industry productivity.

The estimation of the cost function of a sector captures the effects of a change in the stock of public capital on productivity as a result of an improvement of public capital used by the sector. Hence, this reduces the cost to produce one unit of the good or service. Then, it captures the impact on the industry's input demand if public capital is a substitute or a complement to private inputs. For instance, the construction of a new highway reduces the travel time a transport firm's employees which reduce the number of transport vehicle the firm needs to operate, thus reducing its costs. Moreover, the change in cost of production of a sector induced by a change in the public capital stock acts as an incentive to adjust the sectoral output. The cost function is estimated with a translog function as represented by equation (6):

$$(6)\ \ln \dot{C} = \alpha_0 + \alpha_K \ln \hat{w}_K + \alpha_L \ln \hat{w}_L + \alpha_Y \ln Y + \alpha_G \ln G + \alpha_t t$$
$$+ \frac{1}{2}[\alpha_{KK} (\ln \hat{w}_K)^2 + \alpha_{LL} (\ln \hat{w}_L)^2 + \alpha_{YY} (\ln Y)^2 + \alpha_{GG} (\ln G)^2 + \alpha_{tt} t]$$
$$+\alpha_{KL} \ln \hat{w}_K \ln \hat{w}_L + \alpha_{KY} \ln \hat{w}_K \ln Y + \alpha_{KG} \ln \hat{w}_K \ln G + \alpha_{Kt} \ln \hat{w}_K\, t$$
$$+\alpha_{LY} \ln \hat{w}_L \ln Y + \alpha_{LG} \ln \hat{w}_L \ln G + \alpha_{Lt} \ln \hat{w}_L \ln t + \alpha_{YG} \ln Y \ln G + \alpha_{Yt} \ln Y\, t + \alpha_{Gt} \ln Gt$$

and the share equations:

$$(7)\qquad S_K = \alpha_K + \alpha_{KK} \ln \hat{w}_K + \alpha_{YK} \ln Y + \alpha_{KL} \ln \hat{w}_K + \alpha_{KG} \ln G + \alpha_{Kt} t$$
$$S_L = \alpha_L + \alpha_{KL} \ln \hat{w}_K + \alpha_{YL} \ln Y + \alpha_{LL} \ln \hat{w}_L + \alpha_{LG} \ln G + \alpha_{Lt} t$$

where $\dot{C}$ is the total cost, $\hat{w}_K$ and $\hat{w}_L$ the relative prices of capital and labour, G is the level of public capital, Y is the output, and t is an index of technical change.[3]

The estimation of the demand function (eq. 8) allows identifying two important parameters: the elasticity of demand with respect to price and elasticity of income per capita.

$$(8)\qquad \dot{Y} = \lambda + \alpha(\dot{P}_Y - \dot{P}_D) + \beta\dot{Z} + (1-\beta)\dot{N}$$

where $\dot{Y}$, $\dot{Z}$ and $\dot{N}$ are respectively growth rates of the output of the sector, GDP, and population, λ is a constant, and $\dot{P}_Y - \dot{P}_D$ represent the growth rate of its output price normalized by the GDP deflator.

Consequently, estimates of the cost elasticity of output and cost elasticity with respect to an increase in public capital as well as the price and income elasticities of demand allow the estimation of the growth in MFP as given by equation (9). It should be noted that the calculation of the growth in multifactor productivity, as opposed to the calculation of multifactor productivity, avoids the methodological and data problems resulting from the comparison of productivity levels.

[3] See Harchaoui et Tarkhani (2003) for more details.

(9) $M\dot{F}P = A[\alpha\eta + \alpha(1+\theta)] + A\alpha\left[\sum_f \pi_f w_f - P_D\right] + A[\lambda + \beta\dot{Z} + (1-\beta)\dot{N}] + \left[A\alpha - \frac{1}{\kappa B}\right]\eta_{CG}\dot{G} + \left[A\alpha - \frac{1}{\kappa B}\right]\dot{T}$,

where $A = \frac{\left[\frac{\kappa - n^*}{\kappa}\right]}{[1-\alpha(\eta-1)]}$, α is the price-elasticity of demand, β the demand income-elasticity per capita, θ is markup over cost, η is the change in the degree of scale, π_f is the share of the f[th] input in private cost, w_f is the growth rate of the industry input prices, P_D is the GDP price deflator, λ is a demand time trend, $\dot{Z}$ and $\dot{N}$ are respectively the growth rate of GDP and population, η_{CG} is the cost elasticity with respect to public capital, κ is the ratio of output price, B is equal to 1-η_{CG}, $\dot{G}$ is the change in the public capital, and $\dot{T}$ is the change in the level of technology. [4]

Four effects can be isolated from equation (9). The impact on the exogenous demand is given by $A[\lambda + \beta Z + (1-\beta)N]$, the effect on input prices is given by $A\alpha\left[\sum_f \pi_f w_f - P_D\right]$, the public capital effect is represented by $\left[A\alpha - \frac{1}{\kappa B}\right]\eta_{CG}G$, and the disembodied technical change is given by $\left[A\alpha - \frac{1}{\kappa B}\right]T$[5]. Since the MFP is in fact the fraction of growth not explained by a dependent variable (the residual), an increase of the capital stock- whether in quantity or quality- that would not have an impact on the MFP growth would be explained either by a total inelasticity of the industry or by the inexistence of a productive component associated with a change in the capital stock.

While Harchaoui and Tarkhani (2003) had access to a large spectrum of data covering several decades, the data for Quebec are more limited. Therefore, we ran the model with data covering 1961 to 2008, disaggregated for 18 industries. The data used to estimate equations (6), (7), and (8) were drawn from CANSIM[6] and KLEMS[7] as we can see in the table below.

[4] As presented in Harchaoui and Tarkhani (2003)
[5] Nadiri and Mamuneas (1994)
[6] Canadian Socio-Economic Information Management System publié par Statistique Canada.
[7] Multifactor Productivity Program by industry or industry KLEMS productivity program establishes the database on productivity by industry that includes multifactor productivity indexes and data on production and capital inputs (K) , labor (L) , energy (E) , materials (M), and services (S) for various industries of the business sector at various levels of aggregation of industries (Statistics Canada 2014).

Table 2 *:* Main data and there source

Variables	Unit	Type of data	Source	
GDP at basic prices	in dollars	provincial	Cansim	Table 379-0025
Investment	in dollars 2012	provincial	Cansim	Table 031-0002
Year-end gross stock	in dollars 2002	provincial	Cansim	Table 031-0002
Total labor compensation for all jobs	in dollars	provincial	Cansim	Table 383-0010
Total compensation per worked hours	in dollars	provincial	Cansim	Table 383-0010
Total compensation of capital per industry	in dollars	provincial	Cansim	
Gross output by industry	in dollars	provincial	Cansim	Table 379-0011
Hours worked	in hours	provincial	Cansim	Table 383-0010
Implicit GDP index	base index 2002	provincial	Cansim	Table 384-0036
GDP growth rates by industry	in %	provincial	Calculated	
Input and output by industry and commodity	in dollars	provincial	Cansim	Table 381-0013
Raw materials price indexes	in % of 1997	Canada	Cansim	Table 330-0006
MFP index by industry	in % of 1997	provincial	KLEMS QUEBEC	Base CLSS
Index of capital service prices	in % of 1997	provincial	KLEMS QUEBEC	
Index of gross output prices	in % of 2002	Canada	KLEMS Canada	
Price Index of intermediate inputs	in % of 2002	Canada	KLEMS Canada	
Price index of labour	in % of 2002	Canada	KLEMS Canada	
Population of Quebec	in persons	provincial	Cansim	Table 051-0005

5. Estimations and results

It is important to highlight that the quality of our estimates were impacted by the scarcity of data at the provincial level compared to what is available at the Canadian level[8]. Incidentally, we had to exclude the public administration sector since we lacked sufficient data for this sector. Moreover, for some variables, namely input prices, the Quebec data was incomplete so we used Canadian prices as an alternative. This solution is relatively common for econometric applications requiring price vectors or price indices in Quebec (see Hébert (1989) and Fortin et al. (2015)). We estimated equation (9) for all industries. Our results for the demand function are summarized in the **Table 3**.

[8] A research assistant spent close to a year exploring options for data we needed for our application.

Table 3 : Demand function estimates

Industries	α	β
Agriculture, forestry, fishing and hunting	-0,2171	0,5692
Mining, quarrying and oil and gas extraction	-0,2596	0,543
Utilities	-0,162	0,0708
Construction	-0,2932	0,6908
Manufacturing	-0,125	0,9224
Wholesale trade	-0,126	0,6447
Retail trade	-0,0282	0,666
Transportation and warehousing	-0,0346	0,469
Information and cultural industries	-0,1893	0,839
Finance, insurance, real estate and rental services, wastes management and waste management and remediation services	-0,0675	0,555
Professional, scientific and technical services	-0,121	0,787
Administrative and support, waste management and remediation services	-0,307	0,495
Educational services	-0,0173	0,265
Healthcare and social assistance	-0,226	0,649
Arts, entertainment and recreation	-0,0405	0,871
Accomodation and food services	-0,123	0,757
Other services, except public administration	-0,0287	0,682
Mean	**-0,1544**	**0,6169**

Note: α is the price-elasticity of demand and β the demand income-elasticity *per capita*.

The price elasticities of demand (α), are negative for all industries and the highest values are found in the construction, the mining-quarrying-oil sector, and the other services, except public administration. For the income elasticities (β), the values are positive for all industries and the highest values are in the manufacturing, the art-leisure-entertainment, and information-cultural industries.

We follow with the estimation of the cost function with equations (7) and (8), where we decompose the growth in average multifactor productivity and results are presented in **Table 4**. For recollection:

(10) $A[\lambda + \beta\dot{Z} + (1-\beta)\dot{N}]$ is the impact on the exogenous demand;

(11) $A\alpha\left[\sum_f \pi_f \dot{w}_f - \dot{P}_D\right]$ is the effect on input prices (relative prices);

(12) $\left[A\alpha - \frac{1}{\kappa B}\right]\dot{T}$ is the effect of disembodied technical change;

(13) $\left[A\alpha - \frac{1}{\kappa B}\right]\eta_{CG}\dot{G}$ is the effect of public capital where η_{CG} is the cost elasticity in respect to public capital ($\frac{\partial \ln \check{C}}{\partial \ln G}$).

Table 4 : Growth of the multifactor productivity by industry (1961-2008)

Industries	Exogenous demand	Relative prices	Technical change	Public capital	Multifactor productivity
Agriculture, forestry, fishing and hunting	0,3003	0,0320	-0,1395	0,0784	0,2713
Mining, quarrying and oil and gas extraction	0,3605	0,0961	0,5685	0,0417	1,0668
Utilities	0,2330	0,0246	0,4172	0,1012	0,7761
Construction	0,3361	0,1414	1,0356	0,1321	1,6453
Manufacturing	0,3612	0,0249	0,3768	0,0269	0,7898
Wholesale trade	0,3468	0,0221	0,2984	0,1385	0,8058
Retail trade	0,3180	0,0047	0,2993	0,1370	0,7590
Transportation and warehousing	0,2698	0,0059	0,2842	0,0432	0,6031
Information and cultural industries	0,3149	0,1653	0,8053	0,0776	1,3632
Finance, insurance, real estate and rental services, wastes management and waste management and remediation services	0,3247	0,0141	0,4950	0,0909	0,9247
Professional, scientific and technical services	0,3836	0,0268	0,6036	0,0883	1,1024
Administrative and support, waste management and remediation services	0,3485	0,0660	0,6723	0,1357	1,2224
Educational services	0,2655	0,0046	0,2483	0,0535	0,5719
Healthcare and social assistance	0,3591	0,0362	0,4851	0,1191	0,9995
Arts, entertainment and recreation	0,4339	0,0083	0,3964	0,0874	0,9260
Accomodation and food services	0,3100	0,0207	0,4979	0,0940	0,9227
Other services, except public administration	0,3261	0,0572	0,7239	0,1320	1,2392

The contribution of disembodied technical change to the growth of the MFP is more important for the service industries than for the primary and the secondary sectors, which is in line with expectations. For instance, we expected that the productivity of an industry such as the information and the cultural industries would be stimulated by technological advancements.

With respect to public capital, it is possible to see that its contribution is stronger in the construction, retail trade, wholesale trade, administrative services, and the other services industries. Although our results confirm a weaker contribution of public capital than those of Harchaoui and Tarkhani (2003), they are nonetheless coherent with their results in terms of general ranking of the effects across sectors. While the methodology differs, the average contribution of public capital to GDP is within the interval estimated by Khanam (1996) at the provincial level. The weaker contribution of public capital to the productivity of the transportation and warehousing sector may seem at first counterintuitive since the road infrastructure network is intrinsically associated with transportation. However, the fact that warehousing is aggregated with transportation decreases the public capital impact on the aggregated sector. Another sector benefiting little from public capital is the mining, quarrying and oil and gas extraction. It should however be noted that the period used for our estimation precedes soaring metal prices and hence the sector experience very slow growth due to international market price. Unlike the oil industry in Western Canada, this particular sector is insignificant in the province of Quebec.

Before the Quebec Infrastructure Program (QIP), Quebec possessed an aging stock of public infrastructures with an accumulated maintenance deficit estimated at 27 billion (Secrétariat du Conseil du Trésor, 2007). The stock of public capital as a percentage of GDP has fallen significantly since the early 80's until the early 2000's (Secrétariat du Conseil du Trésor, 2013). While the province average annual infrastructure investment was $ 2.5 billion between 1997 and 2003, investments resulting from QIP exceeded 8 billion between 2008 and 2011. The use of more disaggregated data has already been raised as a potential obstacle to capture of all the positive externalities of public capital (Nadiri and Mamuneas 1994). The combination of the use of disaggregated data with a low public capital investment over the years considered may explain, at least partially, the lower externalities of public capital that our estimates provide. It should also be noted that the estimates of the contribution of public capital to growth of Khanam (1996) at the national level (0.24 to 0.46) were significantly larger than those estimated at the provincial level (0.08 to 0.12). Notwithstanding these explanations and considering the investments that resulted from the Plan Nord and the QIP in recent years, it would be interesting to revaluate these estimates in a few years to validate if the size of the externalities will increase in this new context.

Meanwhile, it should also be noted that we used a different in the disaggregation of sector compared to Harchaoui and Tarkhani (2003). While their industries lie more at the primary and secondary levels, we were constrained to use the disaggregation of the input-output table for the province of Quebec. Hence we used the disaggregation level S based on the North American Industry Classification System (NAICS). This constraint originates in our initial objective to estimate elasticities that would be feed into a CGE model for the province. Our elasticities had to correspond to the sector found in the CGE model. This difference in the nature of the sectors studied could certainly explain part of the difference in scale of the public capital's contribution to the Quebec economy compared to the Canadian results of Harchaoui and Tarkhani (2003). A final explanation for the lower level of elasticity could be the fact that the province of Quebec has a very large territory. Thus, a transport infrastructure network will not have the same impact in a densely populated area as it will have in a vast, remote, less densely populated area[9].

6. Conclusion

This article aims to estimate the elasticities of public infrastructure in the province of Quebec with respect to sectoral production. Beyond the theoretical issues around this topic, there is undeniable interest in getting a better grasps of the benefits of infrastructure investment given the cost involved which can prove to be a burden to future generation if these benefits are too small. More specifically, a direct application of our estimates involves the incorporation of the productive externality of elasticities of public capital in the CGE model of the Quebec economy. Since Aschauer (1989a) and Munnell (1990), estimation methods have evolved. Consisting mainly of the primal approach in the 90s, the estimation methods of dual estimation and nonparametric gradually replacled estimating the contribution of public capital only by the production function. Drawing on the dual approach used by Harchaoui and Tarkhani (2003), we estimated the demand and cost functions for the Quebec economy for the period 1961-2008. Our results confirm the positive contribution of public capital to production whose average exceeds 0.09. While our results suggest a lower contribution of public capital compared to the estimates of Harchaoui and Tarkhani (2003), it is within the range estimated by Khanam (1996). Some explanations tend justify the lower magnitude that our estimates suggest such as, amongst others, the higher level of disaggregation, the infrastructure underinvestment characterizing the period used for estimation and the differences inherent in sectors considered. In addition, a disaggregation of the capital stock, while unavailable at the time of our study, would add to the level of analysis. This article is therefore part of a growing literature supporting the hypothesis of the positive contribution of public capital on production.

We intend to use the elasticity parameters presented in this article to a computable general equilibrium (CGE) model applied for Quebec. A CGE model is an analytical tool that allows one to integrate various economic agents and production sectors which interact on various markets. The inclusion of elasticity parameters specific to the province of Quebec will enhance the analysis provided by the model.

[9] [9] Note that even if the population density of Quebec (4,9 hab/km2) is higher than that of Canada (3,5 hab/km2), the average weighted population density by the size of provincial economies is 8,1 which is almost twice the density of Quebec.

Bibliography

Ahmed, H., and S. M. Miller, (2000). “Crowding-out and crowding-in effects of the components of government expenditure”. *Contemporary Economic Policy*, 18(1); 124-133.

Aschauer, D., A., (1989a), “Is Public Expenditure Productive?”, *Journal of Monetary Economics*, 23(2); 177-200.

Aschauer, D., A., (1989b), “Public Investment and Productivity Growth in the Group of Seven”, *Economic Perspectives*, 13(5); 17-25.

Barro, R., J., (1990), “Government Spending in a Simple Model of Endogenous Growth”, *Journal of Political Economy*, 98(5); 103-126.

Berg, A., S. Aiyar, M. Hussein, S. Roache, T. Mirzoev and A. Mahone (2007) “The Macroeconomics of Scaling Up Aid: Lessons from Recent Experience” IMF Occasional Paper No. 253, IMF, Washington, D.C.

Berndt, E.,R. and B Hansson, (1992), “Measuring the Contribution of Public Infrastructure Capital in Sweden”, *Scandinavian Journal of Economics*, 94(4); S151-S168.

Boccanfuso, D., and L. Savard, (2010), “Analyse d'impacts de la construction de l'autoroute Dakar-Thiés: Un modéle d'équilibre général calculable multiménages intégré”, *Canadian Journal of Development Studies* 29(3-4); 435-464.

Boccanfuso, D., M. Joanis, P. Richard, and L. Savard (2014), “A comparative analysis of funding schemes for public infrastructure spending in Quebec”, *Applied Economics*, 46(22); 2653-2664.

Bolduc, D., and R. Laferrière, (2001), “Les effets des dépenses d'infrastructures routières sur le développement économique du Québec”. Ministère des Transports, Québec.

Conrad, K., and S. Heng, (2002), “Financing road infrastructure by savings in congestion costs: A CGE analysis”. *The Annals of Regional Science*, 36(1); 107-122.

Dumont, J., C. and S. Mesplé-Somps, (2000), “The Impact of Public Infrastructure on Competitiveness and Growth: A CGE Analysis Applied to Senegal”, Mimeo, CREFA, Université Laval, Québec.

Faini R. (1994), “Investissement public et investissement privé en Afrique : éviction ou entraînement?” in Eds, P. Guillaumont and S. Guillaumont S, Ajustement et Développement, l'expérience des pays ACP, Economica, Paris, 393 p.

Fortin, M., M. Joanis, P. Kabore and L. Savard (2015) Détermination du PIB réel trimestriel du Québec et analyse du cycle économique, 1948-1980, GREDI Working paper #15-XX, Université de Sherbrooke, Sherbrooke.

Frank D and J. Sumpf (1997), Abschätzung der volkswirtschaftlichen Verluste durch Stau im Verkehr, Studie im Auftrag der Bayerischen Motorenwerke, BMW, Verkehr und Umwelt, Munich.

Garcia-Milà, T. and T.J. McGuire, (1992), “The Contribution of Publicly Provided Inputs to States’ Economies”, *Regional Science and Urban Economics*, 22(2); 229- 241.

Gramlich, E.,M., (1994) “Infrastructure Investment: A Review Essay”, *Journal of Economic Literature*, Vol.32, N° 3, pages1176-1196.

Gu, W., and R. Macdonald. (2009). “The Impact of Public Infrastructure on Canadian Multifactor Productivity Estimates”. Statistics Canada Catalogue no. 15-206-X. Ottawa. *The Canadian Productivity Review*. No. 21.

Harchaoui, T., and Tarkhani, F., (2003), “Public Capital and Its Contribution to the Productivity Performance of the Canadian Business Sector,” Economic analysis (EA) research paper series no. 017, Statistics Canada, Ottawa, Canada.

Hébert, G. 1989. Les comptes économiques de 1926 à 1987. *Le Québec statistique*, 59e édition, Quebec, Publications of the government of Quebec., pages. 45-67

Henderson, D. J., and S. C. Kumbhakart, (2006), "Public and Private Capital Productivity Puzzle: A Nonparametric Approach". *Southern Economic Journal*, 73(1); 219-232.

Hulten, C.R., and R.M. Schwab, (1991), "Public Capital Formation and the Growth of Regional Manufacturing Industries," *National Tax Journal*, 44(4);121-134.

Hurlin, C. (1999), "La Contribution Productive du Capital Public à la Croissance : Estimation sur un Panel Sectoriel de dix pays de l'OCDE", *Économie et Prévision*, 137(1); 49-65.

Khanam, B., (1996), "Macroeconomic Performance and Public Highway Infrastructure," *TP 12792E*, Transports Canada, Ottawa, Canada.

Li, Y., and F. Rowe, (2007), "Aid inflows and the real effective exchange rate in Tanzania", World Bank Policy Research Working Paper 4456, World Bank, Washington, D.C.

Lynde, C. and J. Richmond, (1993), "Public Capital and Long-Run Costs in U.K. Manufacturing". *The Economic Journal*, 103(419); 880-893.

Macdonald, R. 2008. *An Examination of Public Capital's Role in Production.* Statistics Canada Catalogue no. 11F0027M. Economic Analysis (EA) Research Paper Series. No. 50, Ottawa, Canada.

Mongardini, J., and B. Rayner, (2009), "Grants, Remittances and the Equilibrium Real Exchange Rate in Sub-Saharan African Countries," IMF Working Paper WP/09/75, IMF Washington, D.C.

Munk, K. (2006). "Assessment of the introduction of road pricing using a Computable General Equilibrium model". Aarhus University Economics Paper, (2005-23).

Munnell, A.H. (1990), "Why has productivity declined? Productivity and public investment", *New England Economic Review*, Jan/Feb (1990); 3-22.

Munnell, A.H. and L.H. Cook, (1990), "How does Public Infrastructure Affect Regional Economic Performance?" *New England Economic Review*, Sept/Oct (1990); 11-33.

Munnell, A.H. (1992), "Policy Watch: Infrastructure Investment and Economic Growth", *Journal of Economic Perspectives*, 6(4); 189-198.

Nadiri, M.I., and T.P. Mamuneas, (1994), "The Effects of Public Infrastructure and R&D Capital on the Cost Structure and Performance of U.S. Manufacturing Industries", *The Review of Economics and Statistics* 76(1); 22-37.

Prud'homme, R. (1996), "Assessing the role of infrastructure in France by means of regionally estimated production functions", in Eds. Batten, D.F, and C. Karlsson, *Infrastructure and the Complexity of Economic Development*, Springer-Verlag, New York.

Racine, J., and Q. Li (2004). "Nonparametric Estimation of Regression Functionswith Both Categorical and Continuous Data", *Journal of Econometrics* 119(1); 99-130.

Secrétariat du Conseil du Trésor-SCT (2007), "Des fondations pour réussir: Plan québécois des infrastructures", Gouvernment of Quebec, Quebec, City, 15 pages.

Secrétariat du Conseil du Trésor-SCT (2013), "Plan québecois des infrastructure: 2013-2023", Gouvernment of Quebec, Quebec, City, 44 pages.

Statitics Canada (2014), http://www.statcan.gc.ca/pub/15-206-x/15-206-x2007014-fra.htm, consulted on May 21th 2014.

Tatom, J.A., (1991), "Public Capital and Private Sector Performance", *Federal Reserve Bank of St. Louis Review*, 73(3); 3-15.