"NEW" PUBLIC INVESTMENT AND/OR PUBLIC CAPITAL MAINTENANCE FOR GROWTH? THE CANADIAN EXPERIENCE

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The article revisits the relationship between growth and public productive expenditures by investigating the growth impact of "new" public investment along with maintenance expenditures in public capital. We sketch out the importance of these components of public capital expenditures for growth and then use survey data from Canada to assess the impact of these variables on Canadian growth. We find evidence that the Canadian economy would benefit from a fall in total public capital expenditures and from a reallocation between new public investment and maintenance expenditures. We also identify the growth impact of the associated sectoral public capital expenditures. (*JEL* E22, E62, H21, H54)

I. INTRODUCTION

In search of the determinants of long-run growth, a strand of the relevant literature has focused on the growth impact of public productive expenditures. The theoretical work of Barro (1990), Barro and Sala-i-Martin (1992), and others and the empirical evidence by several studies (surveyed by Gemmel and Kneller 2001) have stressed the role of government productive activities as key determinants of long-run growth.

The impact of public expenditures typically takes the form of positive production externalities that enhance private sector productivity via private firms' production function either as a flow (government productive services) or as a stock (public or infrastructural capital).[1] The adoption of this framework embeds two central assumptions on the nature of public capital expenditures. First, all expenditures related to the public capital accumulation process of the economy are oriented to the formation of "new" public capital through investment. Second, public capital deterioration is considered as an exogenously given technical relationship. Hence, this approach neglects a crucial choice concerning the implementation of public investment decisions, namely, the choice between investing in new public capital and extending the durability of the existing public capital stock. The cost paid for the latter option is usually called "maintenance expenditures for public capital" and, strictly speaking, should be classified under the budgetary term "public investment" because it fulfills two basic criteria: (1) It is financed by taxation or government borrowing and (2) it does not result in public consumption expenditures, but instead increases the public capital stock available in the economy.[2]

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1. For the rest of the article, the terms *public capital stock* and *infrastructure* shall be used interchangeably.

2. The issue of capital maintenance is not new in the literature. In a series of papers during the 1970s, several authors investigated the private firm's problem between optimal maintenance level and the maintenance dependent depreciation rate; see, among others, Schmalensee (1974), Feldstein and Rothschild (1974), Su (1975), and Parks (1979). Subsequent empirical studies found that although decaying constant rates of depreciation often provide a reasonable approximation at a given point in time, there is mounting evidence that capital deterioration is endogenous and, in particular, associated with maintenance expenditure; for a brief survey of related empirical findings, see Nelson and Caputo (1997). More recent strands of the theoretical literature investigate the role of private maintenance in aggregate models of the business cycle (Collard and Kollintzas 2000), on capital utilization at the firm level (Licandro and Puch 2000) or at the aggregate level (Aznar-Marquez and Ruiz-Tamarit 2001; Licandro et al. 2001), and the complementarity or substitutability between maintenance and investment (Boucekkine and Ruiz-Tamarit, 2003).

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Despite the intuitive consensus on the crucial weight of maintenance expenditures in public capital and the trade-off with expenditures in new public investment, there have been few systematic attempts to investigate their macroeconomic impact. An attempt to analyze this trade-off has been recently made by Rioja (2003), who sets up a growth model where domestic tax revenues finance maintenance expenditures for public capital, whereas public infrastructure is financed solely by foreign donors. The author shows that the optimal maintenance level as a share of output depends on various parameters and presents calibration results from Latin American countries that confirm the importance of maintenance for the pattern of growth in these countries. Along this line, Kalaitzidakis and Kalyvitis (2004) extend Rioja's model by concentrating on the implications of maintenance expenditures for public capital formation on growth. In their model, both types of expenditures are financed by a tax on output; by altering their allocation, the government can use the share of maintenance as a policy instrument and raise the shadow value of private capital, thus leading the economy to a higher growth rate. An appealing implication is that the growth-maximizing share of taxation is higher than the elasticity of public capital in the production function (which reverses a standard argument put forward by, among others, Barro 1990; Glomm and Ravikumar 1994; Devarajan et al. 1998), as the additional positive effect of maintenance expenditure on the accumulation of public capital raises the benefits of taxation compared to the standard models.

Although theoretically sound, these relationships do not translate easily into operational guidelines for policy makers on the growth effects of maintenance and new public capital expenditures.[3] Ideally, one would like to test these implications in the context of a wide cross-country data set consisting of data on each of the two components of public expenditures. Unfortunately, published data on maintenance are very scarce, involving only a handful of private activities due to inherent problems in the measurement of this type of expenditures. McGrattan and Schmitz (1999) describe the difficulties in constructing aggregate measures of maintenance and repair; the authors point out that, for instance, in the United States maintenance activities are largely carried out outside the market and, thus, recorded transactions are usually incomplete. When such transactions exist, there is no systematic data collection, except for some scanty manufacturing data.[4]

Globally, there has been only one source of long-run data on maintenance expenditures, namely the Canadian survey on Capital and Repair Expenditures, which contains evidence on maintenance expenditures of both private firms and government organizations. The figures show that total private and public maintenance and repair expenditures in Canada amounted on average to around 6.3% of gross domestic product (GDP) for the period 1956–93.[5] This figure was roughly equal to one-third of spending on new investments and, when compared to other so-called engines of growth, was somewhat lower than education spending (6.8% of GDP), but far above the average spending on research and development (1.4% of GDP). Regarding public sector expenditures in maintenance, 21% of total public capital spending went to maintenance and repair expenditures, but with considerable variations across sectors of public activity (which in Canada consists of government-owned enterprises, government institutions-housing, and government departments).

The purpose of the current article is to shed some light on the empirical relationship between maintenance expenditures in public capital, new public investment, and growth. In particular, we use this unexploited Canadian data set to test the impact of total public capital expenditures and their components on growth. We place emphasis on the growth rate because given the importance of economic growth in

3. Existing work on maintenance expenditures in public capital is usually performed in the context of cost-benefit analysis and is primarily concerned with road damage and optimal user charges, which rely on required repairs and their timing; see Newbery (1988). Another type of project-based analysis is conducted in terms of 'recurrent' expenditures, which are the "operations and maintenance expenditures needed to run the project at a level consistent with its expected use, and to maintain the capacity of the investment during its expected lifetime" (Hood et al. 2002).

4. One such source for manufacturing is the *Survey of Business' Plans for New Plants and Equipment* utilized by Feldstein and Foot (1971) and Eisner (1972). According to the figures quoted in these papers, replacement expenditure in the United States amounted to around 60% of planned investment in manufacturing for the 1949–68 period.

5. The private sector consists of the business sector and the private institutions-housing sector.

improving living standards, modern growth theory has shown particular interest in growth-enhancing policies. The understanding of the forces of economic growth, which covers the theoretical and empirical analysis of the growth-driving factors and policies, is crucial to identify the relative merits, synergies, and impacts of government interventions in areas like the formation and allocation of public infrastructure that is examined here. Moreover, the growth rate is usually one of the main measurable objectives of governments, and hence it is useful to know the contribution of the components of public expenditures aiming at public capital formation (see also Devarajan et al. 1996).

Our empirical results indicate that the Canadian economy would benefit from a fall in total expenditures on both new capital and maintenance and that the aggregate share of maintenance in total expenditures should be lower over the period under consideration. Moreover, the disaggregation of these expenditures by sector of public economic activity yields interesting policy insights on the allocation among sectors. The evidence shows that the decrease in total expenditures should come mainly from expenditures in government-owned enterprises and government departments. Of interest is also the allocation between new capital and maintenance expenditures at the sectoral level. According to the evidence, the suggested decrease of the maintenance share should come mainly from maintenance expenditures in government-owned enterprises.

We think that the results of the article highlight another possible classification of public expenditures in accordance to the spirit of the empirical work by Devarajan et al. (1996), Kneller et al. (1999), and Bleaney et al. (2001). All these authors classified public investment expenditures in two broad categories, namely, productive and unproductive expenditures, and confirmed that their growth impact differs dramatically, with productive expenditures exerting a positive influence on growth, whereas unproductive ones have virtually no impact. Albeit confined to a single economy (Canada), the evidence of the current article shows that the growth impacts of public capital expenditures in new capital and maintenance are likely to display substantial discrepancies depending on their absolute size and their relative share, thus opening a new route for further empirical explorations on the growth effect of fiscal categories.

The rest of the article is organized as follows. Section II outlines the anticipated growth impact of maintenance expenditures in public capital versus new public investment. Section III describes briefly the Canadian survey on capital and repair expenditures. Section IV outlines the empirical specifications, and section V provides empirical evidence on the impact of aggregated and disaggregated expenditures and of the corresponding maintenance shares on Canadian growth. Section VI concludes.

II. THEORETICAL FOUNDATIONS OF THE GROWTH IMPACT OF MAINTENANCE IN PUBLIC CAPITAL

Maintenance expenditures can be broadly defined as the "employment of resources [...] that preserve the operative state of capital" (Bitros 1976, p. 919). Although several studies have attempted during the past decades to investigate various aspects and impacts of capital maintenance expenditures, few have concentrated on their growth impact (see also the discussion in the previous section). Here we describe more analytically the various channels through which this type of public expenditures is anticipated to affect growth, as they have been pinpointed by the theoretical literature so far.

The first study that underlined the macroeconomic importance of maintenance expenditures in public capital was Rioja (2003), where the author constructs an endogenous growth model in which the depreciation rate of infrastructure is endogenous and depends on maintenance and usage. Maintenance enhances the productivity of private capital by increasing the level of public capital. In Rioja's model, maintenance of public capital is financed by taxation; in contrast, new investment is financed solely by foreign donors.

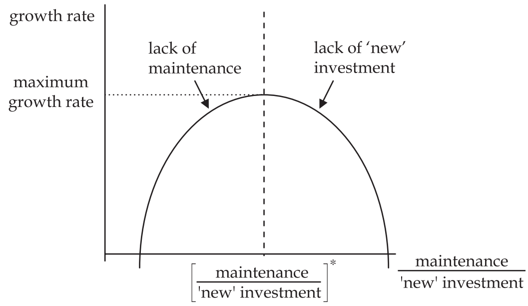
The author is then able to analyze the tradeoff between new investment and maintenance expenditures. Intuitively, if aid-financed new investment as a share of the existing infrastructure stock rises, the optimal maintenance expenditure should decrease. In this setup, the government cares about the overall size of the public capital stock, which affects output and welfare. Hence, as donors fund more new investment, which adds to the existing public capital stock, it is optimal to decrease tax-financed maintenance. A welfare-improving option in this setup is to reallocate a portion of aid-financed new investment toward maintenance. Indeed, the calibration results presented by Rioja (2003) confirm that reallocating some of the donor aid away from new investments and toward maintenance can have positive effects on GDP of Latin American countries.

To extend the concept of maintenance put forward by Rioja (2003) to a more generalized setup, Kalaitzidakis and Kalyvitis (2004) develop an infrastructure-led two-sector endogenous growth model in which the private and the public capital stocks enter directly in the production function. Following Rioja (2003), the authors then assume that the depreciation rate of public capital and consequently its accumulation rate are determined by public expenditures on maintenance. A rise in maintenance expenditures as a ratio of output (where output can be considered as a measure of the burden on public infrastructure) raises the durability of public capital. At the same time, the second component of public capital expenditures, namely, new public investment, adds directly to public capital. Here, following Barro (1990), both types of public expenditures are financed by a proportional tax on the aggregate gross output.

The authors perform comparative statics to examine first whether the economy can benefit from a reallocation between new investment and maintenance at the given taxation rate. A shortage of (or excess in) public capital can be eliminated by the change in allocation between these two components and the subsequent accumulation of infrastructure. In particular, under given total expenditures, if maintenance is at a low (high) level relative to new investment, a shift in the mix toward (from) maintenance reduces (increases) expenditures for new investment. The economy is now able to accumulate public capital at a faster rate by using the same amount of total public expenditures resources, because the improved reallocation triggers a rise in public capital accumulation. Hence, by accumulating more infrastructure, the economy can take advantage of the existing private capital stock. The shadow price of private capital and the growth rate rise as the economy moves toward the new composition between new investment and maintenance. Therefore, the government can improve the growth rate of the economy by altering the share of maintenance expenditures in total expenditures, because at the given government size the economy more efficiently uses the existing private capital stock. The opposite picture emerges when there is a lack of new investment relative to maintenance expenditures. The dynamic relationship between growth and the ratio of maintenance to new investment is depicted in Figure 1.

FIGURE 1

The Relationship between Growth and the Ratio of Maintenance in Public Capital to "New" Public Investment Expenditures



Notice that under this setting, maintenance and new investment are not perfect substitutes, because one unit of the latter adds directly to the public capital stock, whereas the same amount of expenditures on maintenance affects the public capital accumulation rate indirectly through the depreciation rate. An immediate implication is that the implied relationship between growth and the allocation between the two components of public capital expenditures is expected to be nonlinear depending, among other things, on the functional specification of the endogenous depreciation function.

A similar exercise can be performed if, for a given composition between new investment and maintenance, the government changes the level of total public expenditures. The decline (rise) in taxation when the economy is in excess (short of) tax revenues induces (reduces) private capital accumulation as after-tax profits are higher (lower), but at the same time reduces (raises) public capital accumulation as there are less (more) resources for financing new investment and maintenance at the given proportion. The fall (rise) of public infrastructure renders private capital less (more) profitable and its accumulation rate falls (rises) gradually until it reaches the corresponding one of public capital. As a result, the new equilibrium is characterized by higher growth. Hence, the new state of the economy depends on the initial level of the tax rate where the inverse U-shaped tax rate effect, popularized by Barro (1990), is confirmed and intensified by the impact of maintenance expenditures in public capital (see also Barro and Sala-I-Martin 1995, figure 4.1).

The previous analysis highlights the importance of maintenance expenditures in public capital for the growth path of the economy at the theoretical level. In particular, two broad conclusions can be drawn. First, public expenditures in new capital and maintenance should both be examined when analyzing the growth impact of public capital expenditures. Second, the allocation between these two components of public capital expenditures is likely to matter for the growth performance of the economy. Third, the (possibly nnonlinear) relationship between these types of expenditures and growth can go either way because it depends on the current size of these expenditures.

III. THE CANADIAN CAPITAL AND REPAIR EXPENDITURES SURVEY: NATURE OF DATA AND DEFINITIONS

As mentioned in section I, the only available data set worldwide on this type of expenditures is the Canadian survey on Capital and Repair Expenditures. In this section we give a brief description of this data set that will be used later on; for more details the reader is referred to McGrattan and Schmitz (1999).

Private firms, households, and government organizations in Canada were asked in an annual survey over the period 1956–93 about their capital and repair expenditures on equipment and structures. In particular, capital expenditures cover spending devoted to new investment, in accordance to the broad definition given earlier. These include expenditures on (1) fixed assets (such as new buildings, engineering, machinery, and equipment); (2) modifications, additions, major renovations, and work in progress; (3) feasibility studies and general fees; (4) work by own labor force. On the other hand, repair expenditures cover spending devoted to maintenance cost, again in accordance to the broad definition given earlier. These expenditures cover (1) maintenance and repair of nonresidential buildings, other structures, machinery, and equipment; (2) building maintenance; (3) equipment maintenance (vehicles, etc.); (4) repair work by own and outside labor force. Here, we pay particular attention to capital and repair expenditures by the extended public sector (where the government controls more than 50% of the voting rights); apart from "pure" public services, such as departments or their equivalents, this definition also covers other organizations, which operate more independently.

In turn, total public expenditures are disaggregated into expenditures by (1) government-owned enterprises, (2) government institutions and housing, and (3) government departments.[6] Table 1 gives a synoptic presentation of the data for the various categories of the public sector. We also report for comparison purposes the corresponding figures for the private sector (which consists of business and private institutions-housing sectors). The general picture shows that total public expenditures in new investment and maintenance amounted to 7.4% of GDP with the average maintenance share covering 21% (1.5% of GDP). However, there are substantial differences between sectors. In particular, the bulk of public capital expenditures were concentrated in the government-owned enterprises and government departments sectors (90% of total). Also, the average share of maintenance was relatively high in these sectors (23.4% and 20.4% of total expenditures, respectively), whereas in contrast the share of maintenance in the institutions-housing sector was only 14.8% of total capital expenditures.[7]

IV. EMPIRICAL SPECIFICATION

We attempt to quantify empirically the direction of the growth impact of public capital expenditures by using the Canadian survey on public expenditures in new capital and maintenance and developing an empirical framework

6. The classification follows that of Statistics Canada for the Capital and Repair Expenditures survey. There are 19 government departments (and ministries of state) in Canada and more than 100 government institutions, including among others health services, science and research centers, transportation agencies, cultural boards, and financial-economic authorities (like Statistics Canada or the Bank of Canada).

7. Interestingly, the government institutions and housing sector has exhibited the largest variability. We shall not address issues like the relationship between maintenance variability, depreciation, and business cycle fluctuations. For a related paper, see Collard and Kollintzas (2000).

TABLE 1
Basic Statistics of Expenditures in "New" Capital and Maintenance by Sector of Economic Activity: Canada, 1956–93

	Mean	SD	Maximum	Minimum
Public sector				
New capital and maintenance expenditures in government-owned enterprises (% of GDP)	3.4	0.6	4.6	2.5
Maintenance expenditures in government-owned enterprises (% of new capital and maintenance expenditure)	23.4	4.2	33.3	15.1
New capital and maintenance expenditure in government institutions and housing (% of GDP)	0.8	0.3	1.5	0.5
Maintenance expenditures in government institutions and housing (% of new capital and maintenance expenditure)	14.8	7.8	30.7	6.2
New capital and maintenance expenditures in government departments (% of GDP)	3.2	0.6	4.2	2.4
Maintenance expenditures in government departments (% of new capital and maintenance expenditure)	20.4	2.8	25.3	15.0
Total public expenditures in new capital and maintenance (% of GDP)	7.4	1.1	9.5	5.5
Maintenance expenditures in public sector (% of GDP)	1.5	0.2	1.2	1.9
Maintenance expenditures in public sector (% of new capital and maintenance expenditure)	21.0	3.1	27.7	14.7
Private sector				
Total private expenditures in new capital and maintenance (% of GDP)	19.7	1.6	23.8	16.2
Maintenance expenditures in private sector (% of GDP)	4.8	0.5	3.7	5.7
Maintenance expenditures in private sector (% of new capital and maintenance expenditure)	24.3	2.1	28.1	22.4
Total (private + public)				
Total expenditures in new capital and maintenance (% of GDP)	27.1	2.4	33.3	22.5
Total maintenance expenditures (% of GDP)	6.3	0.7	5.1	7.5
Maintenance expenditure (% of new capital and maintenance expenditure)	23.3	1.5	26.7	21.0

Source: CANSIM database, Statistics Canada.

that relates these components of public capital expenditures to Canadian growth. More specifically, the anticipated results involve testing for the links between public expenditures for capital formation, the share of maintenance, and the growth rate of the economy. For instance, a positive effect of the share of maintenance on growth implies that a reallocation of government expenditures toward maintenance will increase the growth rate of the economy. Or, according to Devarajan et al. (1996), maintenance is "productive," and infrastructure investment is "unproductive" at the current allocation of total government expenditure. To this extent, estimation of growth equations, which include the share of maintenance as a key explanatory variable, could reveal whether an economy directs adequate resources toward maintenance. In a similar vein, a positive (negative) impact of total expenditures devoted to new investment and maintenance on the growth rate indicates that a rise (fall) of total expenditures as a fraction of GDP would ceteris paribus enhance (reduce) growth.

There is by now a large body of literature on the empirical impact of public policies on growth, which can be broadly classified into three categories depending on the adopted econometric approach: cross-section, time-series, and pooled cross-section regressions. All studies emphasize the potential importance of various forms of governmental actions (expenditures, taxation, etc.) on the growth pattern of the economy. In our case, to isolate empirically the effect of public infrastructure on growth and private capital in Canada it is essential to take into account all factors that are likely to be of importance.

Therefore, given (1) the theoretical predictions developed in section II, (2) the consideration of the existing empirical literature, and (3) the data set consisting of a single country time-series, the testing strategy involves the following approach. After having adopted the classification of the data for Canada reported previously, the aim is to estimate the effect on growth of (1) the level of total public capital and repair expenditures (the total public capital expenditures effect) and (2) the ratio of maintenance to total public capital and repair expenditures (the maintenance effect).

To this extent, we opt for a general empirical specification of the form *growth rate of Canada* $=f($*control variables, total capital expenditures, maintenance*$)$, where *control variables* indicates a set of other variables that are expected to affect the growth rate of the economy and will be determined later. In this framework, a positive (negative) impact of the share of maintenance on growth would signal that a reallocation of total government expenditures in favor of maintenance (new investment) would be beneficial for the growth rate of the economy. Similarly, the total public capital expenditures effect can be investigated by testing whether *aggregate* public expenditures in new capital formation and maintenance affect (positively or negatively) the growth rate of the economy.

In general, total public capital expenditures, as a ratio to output, and the share of maintenance in these expenditures are expected to be positively related to growth when they are low, but the relationship will become negative when they get relatively large. Thus, one anticipates a *nonlinear* impact of total expenditures and the share of maintenance on growth. Accordingly, a nonlinear empirical specification is adopted with higher-order terms of aggregate expenditures (as GDP%) and the maintenance share included as explanatory variables. The estimated equation takes the following parametric form:

$$(1)\quad g_y^{CANf} = f(control) + \sum_{j=1}^{k} \alpha_j \times ([G+M]/Y)^j + \sum_{j=1}^{l} \beta_j \times (M/[G+M])^j,$$

where g_y^{CANf} denotes the Canadian three-year forward moving average growth rate (for a more detailed discussion see later); G and M denote new public investment and maintenance expenditures in public capital, respectively; and Y denotes output. Hence, $(G + M)/Y$ denotes total (new and maintenance) public capital expenditures as a share of GDP, and $M/(G + M)$ denotes the share of maintenance expenditures in total public expenditures. The order k and l of the two variables of interest is assumed to be unknown and will be determined by the properties of the data. In general, a nonlinear impact (i.e., an order ≥ 2) is predicted, according to the models developed earlier.

The marginal effect of $(G + M)/Y$ and $M/(G + M)$ on growth can then be captured by the partial derivatives evaluated at the mean. Hence, the tested hypotheses on the total expenditure effect are:

$$\text{(Null A)}\quad [\partial g_y^{CANf})/\partial([G+M]/Y)] = 0$$

(total public capital expenditures are not over- or underprovided);

$$\text{(Alternative A1)}\quad [\partial g_y^{CANf})/\partial([G+M]/Y)] < 0$$

(total public capital expenditures are overprovided); and

$$\text{(Alternative A2)}\quad [\partial g_y^{CANf})/\partial([G+M]/Y)] > 0$$

(total public capital expenditures are underprovided).

In an analogous manner, the corresponding tested hypotheses on the marginal growth effect maintenance take the form:

$$\text{(Null B)}\quad [\partial g_y^{CANf})/\partial(M/[G+M])] = 0$$

(maintenance is not over- or underprovided);

$$\text{(Alternative B1)}\quad [\partial g_y^{CANf})/\partial(M/[G+M])] < 0$$

(maintenance is overprovided); and

$$\text{(Alternative B2)}\quad [\partial g_y^{CANf})/\partial(M/[G+M])] > 0$$

(maintenance is underprovided).

This framework allows inference about the growth impact of total public capital expenditures (Null A) and the share of maintenance in total expenditures (Null B). In turn, the rejection of these null hypotheses in either way provides us with evidence on the under- or overprovision of these expenditures.[8]

Furthermore, to refine the analysis and estimate different effects on growth of the different components of capital and repair expenditures, we can use the sectoral survey data on public capital expenditures and maintenance. This exploration at the sectoral level may help us extract all the information reliably contained in the data. So, a similar exercise can be performed using the disaggregated data described in the previous section by estimating an equation that takes the parametric form:

$$(2)\quad g_y^{CANf} = f(control) + \sum_{j=1}^{m}\sum_{i=1}^{3}[\gamma_{i,j} \times ([G+M]_i/Y)^j] + \sum_{j=1}^{n}\sum_{i=1}^{3}[\delta_{i,j} \times (M_i/[G+M]_i)^j].$$

Again, the estimated coefficients for (2) have the same interpretation as those of equation (1), but now refer to the sectoral components, whereas the order m and n of the sectoral variables is assumed to be unknown and will be determined by the properties of the data on hand. Also, the hypotheses A and B and the corresponding alternatives can be interpreted in the same manner with reference to the related sectors.

Turning to the variables at hand, the growth rate for Canada is given by the annual GDP per capita growth rate. To avoid potential endogeneity problems we use as a dependent variable the three-year forward moving average growth rate, in the spirit of Devarajan et al. (1996).[9] This definition also dampens down the business cycle effect on the growth rate. Regarding growth determinants in Canada, most previous studies have placed emphasis on the export-led character of the economy and have paid less attention to domestic factors, like private and public investment expenditures. Following the work of Aschauer (1989), some authors have attempted to investigate the effects of private and public investment on output in Canada. Serletis (1994, 1996) reports that the private and public investment to output ratio is found to be nonstationary. This finding contrasts the prediction of the standard neoclassical growth model and can be considered as favorable for endogenous growth models, where permanent investment policies lead to permanent changes in the growth pattern of the economy. Bodman (1998) stresses the importance of public capital by finding that government infrastructural capital has a significant impact on growth. Wylie (1995, 1996) has found that public infrastructure plays an important in enhancing productivity in Canada with an elasticity that is comparable to the one reported for the United States by Aschauer (1989).

In the current approach, to capture these impacts and verify the robustness of the results we have used several conditioning variables to account mainly for the impact of external shocks, domestic policies, and competitiveness. So we use alternative empirical specifications with the inflation rate, the budget deficit, and the terms of trade growth rate as "control variables" (for a detailed description of all variables see the appendix).[10] More specifically, the inflation rate is always included to capture the well-known negative relationship between inflation and growth. We also include the budget deficit (as a share of output) as a measure of the domestic fiscal stance, which is likely to affect the growth effects of public capital expenditures as Ricardian equivalence might eliminate or mitigate their impact. Finally, the open character

8. In a similar vein, Karras (1996) has used growth accounting to test for the optimal size of the government sector in various economies, as suggested by the standard Barro (1990) model.

9. Due to the presence of overlapping observations and the serial correlation of the residuals, estimation is carried via generalized method of moments with a correction for second-order moving-average autocorrelation. We also experimented with the percentage change between $t+3$ and $t+1$ growth rate as the dependent variable with no substantial changes in the results.

10. We also experimented with other candidate control variables, such as the U.S. growth rate, the degree of openness of the economy (given by the ratio of exports and imports to GDP), the real exchange rate, private investment, and private capital and repair expenditure from the same Canadian survey, but none of these variables yielded plausible or statistically significant coefficients for the corresponding variables. More important, the inclusion of these variables did not alter the significance and magnitude of the coefficients of the public capital expenditures' regressors.

of the Canadian economy and the associated influence of international competitiveness additionally justify the inclusion of the terms of trade growth rate, which is a standard variable in growth regressions.

V. RESULTS

In this section we present the results derived by the empirical specifications developed earlier. We start with the specification for aggregated public capital expenditures, and then we move on to report estimates for sectoral expenditures.

Aggregate Expenditures

We begin the presentation of the empirical results by postulating coefficients of second order for the variables of interest. The empirical results for various forms of this specification are displayed in Table 2. The estimated equations have a high explanatory power of total Canadian growth variability ranging from 78% to 82%. The inflation rate enters with expected negative sign and is significant in all specifications. The remaining two control variables enter with insignificant signs; however, the general picture remains unaltered with respect to the variables of interest, namely, the share of total public capital expenditures in output and the maintenance share in these expenditures.

Specifically, the impact of the latter variables is investigated by equations (1.1) to (1.4) by assuming first- and second-order effects on growth. Turning first to the impact of total public capital expenditures, they enter in all specifications with statistically significant (at the 1% level) positive coefficients for the first-order effect and negative ones for the second-order effect. This evidence implies an inverse U-shaped relationship between growth and these expenditures, which corroborates the expected theoretical nexus developed in section II. The dynamics of the maintenance share are, however, found to be more complicated. Although the variable enters with statistically significant signs in almost all cases in specifications (1.1) to (1.4), the first-order effect is negative and statistically significant, whereas the second-order effect is positive or statistically insignificant. This implies either a U-shaped curve for the relationship between the maintenance share and the growth rate or more complicated dynamics involving higher-order nonlinearities in the relationship between aggregate maintenance allocation and growth due, for instance, to technical needs requiring an effective (upper or lower) bound in the share of these expenditures.

The second part (specifications [1.5] to [1.8]) of Table 2 attempts to explore these issues further by including a third-order effect for the share of maintenance expenditures.[11] The third-order effect is found to be significant in all specifications and improves the statistical significance of the remaining coefficients of the maintenance share, without substantially affecting the results on the coefficients of the control variables or total public capital expenditures. In general, this third-order relationship implies that there are two turning points in the relationship between growth and the share of maintenance, and therefore that the inverse U-shaped relationship holds, but only for a region of the share of maintenance expenditures. A potential explanation for this finding may be related to the aggregated nature of the data at hand. As explained in section III, the broad definition of aggregated expenditures covers various public sector activities, which may operate in the opposite direction regarding their growth effects. Absent any further aggregate evidence related to this finding, we postpone its investigation for the following subsection, where sectoral estimates are examined.

To assess the marginal impact of aggregate public capital expenditures according to hypotheses *A* and *B*, we calculate the corresponding derivates at the mean and we use a standard Wald test to investigate the various hypotheses about the sign of the effects.[12] The results for the aggregate specification are tabulated in the upper part of Table 3. Total capital and repair expenditures are found to have in all specifications a negative marginal impact on growth, which is significant at the 1% significance level. An important policy conclusion obtained by these results is that total expenditures on new capital and maintenance (amounting on average to 7.4% of GDP) have been overprovided for the period

11. We also experimented with other potential specifications, like multiplicative terms or a third-order effect in total public capital expenditures, but no statistically significant results were obtained.

12. Notice that the test statistic is not affected by the presence of the stochastic explanatory variables; see, for example, Greene (2000).

TABLE 2

The Effects of Aggregated Public Expenditures in “New” Capital and Maintenance on Canadian Growth: Nonlinear Effects (Dependent Variable: Three-Year Forward Moving Average of GDP per Capita Growth Rate)

Independent Variable	**Eq. (1.1)**	**Eq. (1.2)**	**Eq. (1.3)**	**Eq. (1.4)**	**Eq. (1.5)**	**Eq. (1.6)**	**Eq. (1.7)**	**Eq. (1.8)**
Constant	2.28 (20.47)	5.14 (20.05)	2.62 (20.43)	5.11 (20.13)	−167.36 (58.21)**	−173.54 (64.29)**	−189.06 (63.00)**	−185.80 (65.89)**
Inflation	−0.35 (0.14)*	−0.31 (0.14)*	−0.35 (0.14)*	−0.30 (0.15)*	−0.37 (0.12)**	−0.38 (0.13)**	−0.36 (0.12)**	−0.35 (0.13)**
Budget deficit	—	−0.16 (0.17)	—	0.18 (0.19)	—	−0.03 (0.16)	—	−0.03 (0.17)
Terms of trade growth rate	—	—	0.02 (0.10)	0.03 (0.11)	—	—	−0.09 (0.09)	−0.09 (0.10)
Aggregated public sector								
Capital and repair expenditures	18.15 (5.33)**	17.09 (5.33)**	18.11 (5.31)**	16.97 (5.36)**	21.08 (4.57)**	21.41 (4.83)**	21.57 (4.64)**	21.35 (4.86)**
(Capital and repair expenditures)^2	−1.32 (0.34)**	−1.26 (0.34)**	−1.32 (0.34)**	−1.26 (0.34)**	−1.50 (0.29)**	−1.52 (0.30)**	−1.54 (0.30)**	−1.52 (0.31)**
Maintenance	−4.02 (1.50)**	−3.84 (1.46)**	−4.05 (1.50)**	−3.77 (1.49)**	19.44 (7.86)*	20.17 (8.46)*	22.37 (8.52)**	22.01 (8.75)*
(Maintenance)^2	0.07 (0.04)*	0.06 (0.03)	0.07 (0.04)*	0.06 (0.04)	−1.08 (0.38)**	−1.11 (0.41)**	−1.22 (0.41)**	−1.20 (0.42)**
(Maintenance)^3	—	—	—	—	0.02 (0.01)**	0.02 (0.01)*	0.02 (0.01)**	0.02 (0.01)*
R^2 adjusted	0.79	0.78	0.78	0.78	0.82	0.82	0.82	0.82
D-W	1.22	1.33	1.25	1.30	1.62	1.61	1.49	1.48

Notes: “Capital and repair expenditures” denotes total public expenditures in new capital and maintenance (GDP %) and “Maintenance” the share of maintenance in total public expenditure, respectively. Estimation method is generalized method of means with correction for second-order autocorrelation. SEs are in parentheses. An asterisk denotes significance at the 5% level and two asterisks at the 1% level.

TABLE 3
Summarized Estimates of Nonlinear Impact on Canadian Growth based on Tables 2 and 4

	Aggregated			
	Eq. (1.1)	**Eq. (1.2)**	**Eq. (1.3)**	**Eq. (1.4)**
Total capital and repair expenditures	Negative**	Negative**	Negative**	Negative**
Maintenance share	Negative**	Negative**	Negative**	Negative**
	Eq. (1.5)	**Eq. (1.6)**	**Eq. (1.7)**	**Eq. (1.8)**
Total capital and repair expenditures	Negative**	Negative**	Negative**	Negative**
Maintenance share	Negative**	Negative**	Negative**	Negative**
	Disaggregated			
	Eq. (2.1)	**Eq. (2.2)**	**Eq. (2.3)**	**Eq. (2.4)**
Government-owned enterprises				
Total capital and repair expenditures	Negative**	Negative**	Negative**	Negative**
Maintenance share	Negative**	Negative**	Negative**	Negative**
Government institutions and housing				
Total capital and repair expenditures	Zero	Zero	Zero	Zero
Maintenance share	Zero	Zero	Zero	Zero
Government departments				
Total capital and repair expenditures	Negative*	Zero	Negative*	Zero
Maintenance share	Zero	Zero	Zero	Zero

Notes: The effects are estimated from a Wald statistic based on the partial derivatives test (see section IV in text). An asterisk denotes significance at the 5% level and two asterisks at the 1% level.

under investigation. Moreover, a negative marginal growth impact is found for the share of maintenance in these expenditures (which amount on average to 21% of total public capital expenditures), indicating that the Canadian economy could benefit from a reallocation between maintenance and new investment expenditures in favor of the latter. Therefore, the overall conclusion is that for the period under consideration the Canadian economy would benefit from a fall in expenditures for public capital formation, which should largely come from a reduction in the share of maintenance expenditure.

An interesting conjecture derived by the aforementioned results regards the growth-maximizing shares of, first, the total public capital expenditures in output and, second, maintenance expenditures. In particular, the estimated coefficients imply that an increase in total public capital expenditures is productive (enhances growth) until these expenditures reach a critical level of 6.7%–7.0% of GDP depending on the specification used and reduce growth thereafter. Similarly, according to the implied shape of the growth-maintenance share relationship, the inferred turning point (corresponding to the maximum in Figure 1) is in the region of 14.1%–14.6% of total expenditures depending on the specification used.[13]

We close this section by noting that at first glance, these results appear to be in contradiction with the usual finding of a positive impact of expenditures for public capital formation in Canada and other developed economies. However, taking into account the budgetary

13. As suggested by a referee, an alternative route to derive an indication about the implied impact in these relationships could rely on the search of a threshold effect (see, e.g., Khan and Senhadji 2001). Preliminary evidence (available on request) indeed confirmed that the within-sample inflexion point occurs at a low level of total public capital expenditures, which was at the region of 6.6%–6.7% of GDP and is very close to the implied growth-maximizing share given in the text. However, the corresponding within-sample threshold for the share of maintenance was at 18.6%–18.8% of total expenditures and is higher than the growth-maximizing one implied by the approach adopted here. Absent a strict theoretical formulation leading to a precise parametric specification where the growth-maximizing levels can be directly identified and estimated, we consider this evidence as an overall confirmation of the findings reported in Table 3 and of the associated policy implications.

TABLE 4
The Effects of Sectoral Public Expenditures in "New" Capital and Maintenance on Canadian Growth (Dependent Variable: Three-Year Forward Moving Average of GDP per Capita Growth Rate)

Independent Variable	Eq. (2.1)	Eq. (2.2)	Eq. (2.3)	Eq. (2.4)
Constant	89.16 (44.99)*	67.05 (46.27)	89.27 (44.98)*	66.28 (46.23)
Inflation	−0.07 (0.15)	−0.07 (0.18)	−0.09 (0.18)	0.04 (0.19)
Budget deficit	—	−0.39 (0.28)	—	−0.40 (0.28)
Terms of trade growth rate	—	—	0.02 (0.11)	0.04 (0.11)
Government-owned enterprises				
Capital and repair expenditures	−11.87 (11.31)	−8.24 (11.41)	−12.33 (11.82)	−9.24 (11.77)
(Capital and repair expenditures)^2	0.84 (1.48)	0.32 (1.50)	0.92 (1.58)	0.49 (1.58)
Maintenance	−1.96 (0.90)*	−2.08 (0.89)*	−1.95 (0.90)*	−2.06 (0.89)*
(Maintenance)^2	0.02 (0.02)	0.03 (0.02)	0.02 (0.02)	0.03 (0.02)
Government institutions and housing				
Capital and repair expenditures	19.37 (14.82)	22.31 (14.81)	19.45 (14.77)	22.64 (14.71)
(Capital and repair expenditures)^2	−7.27 (6.40)	−9.55 (6.55)	−7.25 (6.39)	−9.62 (6.50)
Maintenance	1.43 (0.52)**	0.94 (0.61)	1.45 (0.52)**	0.97 (0.61)
(Maintenance)^2	−0.05 (0.01)**	−0.04 (0.01)*	−0.05 (0.01)**	−0.04 (0.01)*
Government departments				
Capital and repair expenditures	−7.29 (15.40)	−3.49 (15.24)	−6.73 (15.72)	−1.91 (15.62)
(Capital and repair expenditures)^2	0.62 (2.26)	0.13 (2.23)	0.54 (2.32)	−0.11 (2.29)
Maintenance	−1.70 (1.59)	−0.64 (1.69)	−1.76 (1.62)	−0.75 (1.70)
(Maintenance)^2	0.03 (0.04)	0.01 (0.04)	0.03 (0.04)	0.01 (0.04)
R^2 adjusted	0.80	0.80	0.79	0.80
D-W	1.72	1.65	1.74	1.69

Notes: "Capital and repair expenditures" denotes sectoral public expenditures in new capital and maintenance (GDP %) and "Maintenance" the share of maintenance in sectoral expenditure, respectively. Estimation method is generalized method of means with correction for second-order autocorrelation. SEs are in parentheses. An asterisk denotes significance at the 5% level and two asterisks at the 1% level.

restriction, it is likely that these expenditures have been far above the desired level, generating persistent deficits in the post-1974 period, which have been inadequate in fostering long-term growth. Another potential explanation for the negative impact of total expenditures in public capital formation on growth may be that previous studies have failed to take into account maintenance expenditures (because their estimates were based solely on the impact of public investment recorded in national accounts). This may have led to an underestimation of the size of aggregate public expenditures and the consequent distortions in the economy.

Finally, another potential source driving the negative impact of maintenance expenditures on future growth may be reverse causality.[14] In particular, a higher future growth rate may lessen the need for expansionary demand-driven policies by use of new investment. Hence, there may be more resources available to the government for maintenance expenditures, thus generating an apparent positive correlation between current maintenance expenditures and future growth, which may explain the finding of maintenance over-provision.

Sectoral Expenditures

As discussed earlier, the composition of public capital expenditures varies considerably across public sectors in Canada. So, to further explore the sources of growth impacts, additional information about can be gained by turning to sectoral estimates (reported in Table 4). The control variables enter with correctly signed but statistically insignificant signs in the estimated specifications (2.1) to (2.4). Nevertheless, the overall picture with respect to the

14. We thank a referee for pointing this potential explanation to us.

variables of interest seems again robust with respect to various alterations with the explanatory power of the equations being again high (approximating 80%).

To capture the effects of the variables of interest (sectoral expenditures and sectoral maintenance shares), their first- and second-order effects are included in the estimated regressions. These specifications are found to be adequate here, because higher-order specifications did not yield statistically significant results. As in the case of aggregate estimates, a direct picture on their marginal growth effects of sectoral public capital expenditures can be obtained by examining the statistical significance of the corresponding partial derivates. These are tabulated in the second part of Table 3. According to the evidence, the marginal growth impact of total capital expenditures by government-owned enterprises is negative. This also holds for the share devoted to maintenance expenditures, which is found to exert a negative marginal impact on growth. These findings are statistically significant at the 1% level and are consistent with the high average level of public capital expenditures (3.4% of GDP) and the high average share (23.4%) of maintenance expenditures in this sector.

The results are less conclusive for government departments, which also have a relatively large average size (amounting to 3.2% of GDP over the period under investigation), but appear to have exerted a negative marginal impact on growth only in two out of four specifications. In contrast, total expenditures in the government institutions-housing (which amount only to 0.8% of GDP), as well as the shares of maintenance in the government institutions-housing and government departments sectors appear to have been at their growth-maximizing levels. (Recall that the shares of maintenance in these sectors were 14.8% and 20.4% of total expenditures, respectively.)

To sum up, the sectoral evidence points out that the reduction in total public capital expenditures suggested in the previous subsection should come from reductions in government-owned enterprises and government departments sectors, which also have the largest sizes in terms of output. Also, it appears that the average share of maintenance expenditures in the government-owned enterprises sector, which is the highest one among the three sectors, should be reduced to improve the growth performance of the Canadian economy.

VI. CONCLUDING REMARKS

The main goal of the article was to highlight empirically the growth aspects of a component of public expenditures, namely, maintenance expenditures in public capital, which had been until now unexplored. Along this line, we attempted to obtain some evidence on the growth impact of public capital and maintenance expenditures in Canada. Our empirical estimates give some interesting policy implications on the size of total public capital expenditures and the impact of maintenance. We therefore think that the article makes a persuasive case for a strong link between maintenance expenditures, new investment, and growth. The empirical findings support the view that maintenance expenditures in the public sector are a crucial determinant of growth, whose impact should be examined in conjunction with that of expenditures in new capital formation advocated by standard growth models.

Although our results are confined to the Canadian economy, it is confirmed that maintenance is an important source of expenditures on public capital, whose impact has remained inadequately explored. Yet the broad cross-country empirical testing of the relationships outlined in the article is, at the present stage of data availability, not possible. Maintenance traditionally appears under various categories in national accounts systems, such as repairs or renovations. With the exception of Canada, there has been no particular interest in collecting data on maintenance expenditures in public capital, although scarce existing evidence from other sectors of economic activity reveals that maintenance in developed economies covers a substantial fraction of total expenditures for capital formation. This lack of data is largely due to the nature of maintenance expenditures: Because there is no market and recorded transactions for maintenance, data collection requires the planning of surveys in public organizations to obtain an accurate estimate of maintenance expenditures and their effect on the depreciation rate of public capital.

The article hopefully offers a rationale for several potential extensions. On the theoretical side, the macroeconomic implications of public capital and maintenance expenditures can be investigated in the context of private and public sector cooperation, including the cost and effectiveness of new public investment and maintenance expenditures. On the empirical side, greater awareness and understanding of long-term growth implications of public capital expenditures along with a greater focus on setting more precise objectives to be pursued by government organizations would facilitate better budgetary decision making and enhance public reporting of the macroeconomic costs and benefits regarding government productive activities. To this extent, data collection in the public sector on these expenditures either by a unified survey or by the inclusion of related questions in existing surveys would yield valuable information for the conduct of efficient public sector management.

Finally, further work on the impact of maintenance expenditures could focus on the regional aspects of these activities. Several types of infrastructure projects often involve small-scale interventions (like public schools or hospitals), which are largely effective at the local level, but whose impact may not appear equally powerful at the national level. It would be therefore of interest for policy makers to know if and by how much maintenance activities affect primarily the local economy or display wider spillover effects. Attempting to answer this open issue might provide an indication regarding the desired degree of designation of the management of this type of expenditures to state or local authorities.

DATA APPENDIX

The first part of the appendix gives the sources for public capital and repair expenditures (for a general description of the variables, see section IV).

1. Total public capital and repair expenditures: *CANSIM* variable D843829.
2. Total public repair expenditures: *CANSIM* variable D843830.
3. Capital and repair expenditures by government-owned enterprises: *CANSIM* variable D843808.
4. Repair expenditures by government-owned enterprises: *CANSIM* variable D843809.
5. Capital and repair expenditures by government institutions and housing: *CANSIM* variable D843812.
6. Repair expenditures by government-owned institutions and housing: *CANSIM* variable D843813.
7. Capital and repair expenditures by government departments: *CANSIM* variable D843816.
8. Repair expenditures by government departments: *CANSIM* variable D843817.

The second part of the appendix describes the rest of the Canadian variables.

1. GDP per capita growth rate: difference in growth rates of Canada GDP (*IFS* variable 15699B.CZF . . .) and Canada population (*IFS* variable 15699Z..ZF . . .).
2. Inflation rate: percentage difference in Consumer Price Index (*IFS* variable 15664 . . . ZF . . .).
3. Budget deficit as GDP percent (*IFS* variable 15680 . . . ZF . . . divided by GDP as defined).
4. Terms of trade growth rate: ratio of export price index (implicit price index for exports of goods and services, Datastream Code CND20570) to import price index (implicit price index for imports of goods and services, Datastream Code CND20573).

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