

Maintenance and Repair: Too Big to Ignore

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Abstract

Most models of aggregate economic activity, like the standard neoclassical growth model, ignore the fact that equipment and structures are maintained and repaired. Once physical capital is purchased in these models, there are typically no more decisions made regarding its use. The theme of this article is that there is evidence to suggest that incorporating expenditures on the maintenance and repair of physical capital into models of aggregate economic activity will change the quantitative answers to some key questions that have been addressed with these models. This evidence is primarily from a little-used economywide survey in Canada. The survey shows that the activity of maintaining and repairing equipment and structures is an activity that is generally both large relative to investment and a substitute for investment to some extent—and to a large extent during some episodes.

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Most models of aggregate economic activity, like the standard neoclassical growth model, ignore the fact that equipment and structures are maintained and repaired. Once physical capital is purchased in these models, there are typically no more decisions made regarding its use. The theme of this article is that there is evidence to suggest that incorporating expenditures on the maintenance and repair of physical capital into models of aggregate economic activity will change the quantitative answers to some key questions that have been addressed with these models. This evidence is primarily from a little-used economywide survey in Canada. The survey shows that the activity of maintaining and repairing equipment and structures is an activity that is generally both large relative to investment and a substitute for investment to some extent—and to a large extent during some episodes.

To illustrate our point that the answers to some key questions may change when spending on maintenance and repair is included in aggregate models, we present a simple representative firm model in which the maintenance and repair activity is a substitute for investment in providing gross capital services. In this model, we ask, What is the effect on the firm's capital intensity of a cut in the capital income tax rate? We show that under reasonable conditions, the size of the increase in the firm's capital intensity as a result of the tax cut depends on whether the model incorporates expenditures on the maintenance and repair of capital: including these expenditures in the model reduces the size of the increase in the firm's capital stock. The reason the tax cut effect on the capital stock is smaller in the model with maintenance and repair is that the model reflects the fact that spending on maintenance and repair is treated differently in many tax codes than investment spending is. Usually, while investment expenditures are capitalized and depreciated over time, maintenance and repair expenditures can be deducted today from revenues in calculating pretax profits. Hence, changes in tax rates influence the firm's spending decision. As tax rates are increased, maintenance and repair spending is substituted for investment. Because this substitute activity is available, the decrease in capital intensity following a tax increase is smaller than it otherwise would be. The same is true, of course, for the opposite direction: when tax rates are cut, the increase in capital intensity is smaller as well.

To keep matters simple, we focus on this single question: What is the impact on a firm's capital intensity of a cut in income tax rates? But it may well be that the answers to many other questions will change as spending on maintenance and repair is included in aggregate models. One key question is, What is the size of the welfare gain from cutting the capital income tax rate? This question has been studied by Lucas (1990) and Laitner (1995), but without attention to the maintenance and repair activity.

The extent to which including maintenance and repair in aggregate models will change their quantitative answers to such questions will depend on the size of these expenditures compared to investment and the extent to which the maintenance and repair activity substitutes for investment. These are some of the data that will be needed to calibrate aggregate models with maintenance and repair. This brings us to the second part of the article, where we discuss the existing evidence on maintenance and repair.

For many countries, like the United States, it is not possible to determine the size of maintenance and repair in the aggregate given current data collection procedures. However, this is not true for Canada: For over 40 years, the government agency Statistics Canada has conducted an annual survey of businesses, government organizations, and households which collects data on maintenance and repair expenditures and investment expenditures for all sectors of the economy.

The Canadian survey shows that maintenance and repair expenditures in Canada are large. Over the period 1961–93, they averaged about 6 percent of the country's gross domestic product (GDP). Over roughly the same period, spending on the maintenance and repair of equipment averaged about 50 percent of spending on new equipment. Spending on maintenance and repair of structures is not as large, averaging about 20 percent of spending on new structures. Spending to maintain and repair both equipment and structures averaged 30 percent of spending on all new physical capital.

The Canadian survey also suggests that the activities of maintenance and repair and investment are to some degree close substitutes for each other. For example, during downturns in economic activity, maintenance and repair spending falls less sharply than investment spending does. During upswings, maintenance and repair spending rises less sharply than investment spending does. Overall, the standard deviation of maintenance and repair expenditures is about 60 percent of the standard deviation of investment expenditures. Within the manufacturing industry, the difference is even more dramatic: there the standard deviation of maintenance and repair expenditures is about 38 percent of the standard deviation of investment expenditures. This suggests that during downturns, new purchases are delayed and older equipment and structures are maintained to a greater extent.

We also look at a particular Canadian industry, the iron ore industry, which in the 1980s faced much more than a typical downturn—its output fell about 50 percent in a year, and its future was extremely uncertain. In this industry, equipment investment spending fell to nearly zero during the period of crisis; yet the industry still spent significant amounts on the maintenance and repair of equipment. (Maintenance and repair expenditures on equipment fell about the same amount as output, that is, in half.) This evidence on the behavior of maintenance and repair spending over the business cycle and in times of crisis suggests a good deal of substitutability between the activities of maintenance and repair and investment.

The organization of the article is as follows. In the next section, we present a standard representative firm model in which the maintenance and repair and investment activities are substitutes in augmenting next period's gross capital services. There we examine the effect of an income tax cut on the firm's capital intensity, asking how adding maintenance and repair to the model changes the model's conclusions. In the following section, we discuss the available data on maintenance and repair. We focus on the Canadian data, though we also discuss the U.S. data, which are much less comprehensive. We close the article with some remarks about the value of the Canadian survey data.

A Simple Model

In this section, we discuss the simplest possible decision problem of a representative firm that can both invest in new capital and maintain and repair its old capital. We then introduce taxes and show how the two activities are often treated differently in the tax code. After these two steps, we show how a cut in income taxes will have a smaller impact on capital intensity in a model which incorporates maintenance and repair.

A Firm's Problem

Consider the problem of a firm that can opt to maintain its capital stock in order to slow the rate at which the capital stock depreciates. (For now, we will ignore the repair function.) The firm uses capital K and labor L to produce a final good Y , $Y = F(K, L)$. The capital stock evolves over time according to the following law of motion:

$$(1) \quad K_{t+1} = [1 - \delta(M_t/K_t)]K_t + X_t$$

where time is indexed by t , X is purchases of new capital goods, M is purchases of maintenance services, and $\delta(M/K)$ is the rate at which the capital stock depreciates.

In most analyses, $\delta(M/K)$ is assumed to be constant. Here we assume that δ is a decreasing function, so that as you increase the maintenance services per unit of the capital stock, you decrease the rate at which capital depreciates, as in Chart 1. In Chart 1, $\delta(0) = 1$, so that if not maintained, the current stock of capital vanishes in one period, and the capital stock next period is equal to investment expenditures this period.

Suppose that the firm sells its output at a unit price, hires labor at a wage w , buys new capital goods at a price p (measured in, say, dollars), and buys maintenance services at a price q (also measured in dollars). The firm's problem is to maximize its discounted profit stream,

$$(2) \quad \sum_{t=0}^{\infty} \prod_{s=0}^t (1+i_s)^{-1} (Y_t - w_t L_t - p_t X_t - q_t M_t)$$

subject to $Y = F(K, L)$ and the law of motion for capital, equation (1). Here i_s is the interest rate in period s .

The relative price of maintenance services to new capital is q/p . In a profit-maximizing solution, this relative price is equated to the benefits of maintenance relative to new investment. If we increase maintenance services by one unit (holding everything else fixed), then next period capital increases by $-\delta'(M/K)$. If we increase new investment by one unit, then next period capital increases by one. Therefore, the maintenance choice satisfies

$$(3) \quad q_t/p_t = -\delta'(M_t/K_t).$$

Recall that δ is a decreasing function, so that $\delta'(M/K) < 0$. Next reconsider the function displayed in Chart 1. The optimal level of maintenance per unit of capital is the point at which the slope of $\delta(\cdot)$ is equal to the relative price. As the price of maintenance services rises, the firm lowers M .

The model thus far only includes maintenance expenditures that affect the rate of depreciation. Some repair expenditures are made after machines break or malfunction—with the capital being offline in the meantime. There is a large engineering literature that models such situations

(cited, for example, in Rust 1987). We could extend the model slightly in this direction by assuming that $Y = F(Ku, L)$, where u is the rate of capital utilization. A value of u less than 1 would imply that only a portion of the capital stock is being used in a productive capacity. If u depends on M , then this is another margin along which a firm can affect its profits. To make our main points, however, we can ignore this curative role of maintenance and repair and work through the example with $u = 1$.

Adding Taxes

Now consider the taxes that the firm pays if there is a percentage tax of τ_t levied on profits in period t . Profits are equal to revenues less current operating expenses. In the tax codes of most countries, purchases of maintenance services qM are treated as current operating expenses. Hence, maintenance and repair expenditures can be fully deducted from revenues before profit taxes are determined. Investment expenditures, or purchases of new capital goods, pX , are not treated as current operating expenses. Rather, these purchases are capitalized and depreciated over time. Depreciation allowances are deducted from revenues.

The depreciation allowances that a firm can deduct from revenues are determined as follows. The firm can typically deduct a certain fraction of the book value of its assets each period as depreciation allowances. Call that fraction d . Denote the period t book value of the firm by B_t (measured in dollars). The book value of a firm's assets at a point in time can be defined recursively. Let B_0 denote the period $t = 0$ book value. Then the period $t = 1$ book value is equal to $B_1 = (1-d)B_0 + p_1 X_1$, where the firm deducts from book value the amount of its depreciation allowances, dB_0 , and adds to book value its new purchases, $p_1 X_1$. In general, the formula for book value is

$$(4) \quad B_{t+1} = (1-d)B_t + p_t X_t$$

To see how these tax provisions will affect the firm's decisions, consider the firm's maximization problem with taxes. The objective is to maximize the discounted stream of revenues less costs and taxes:

$$(5) \quad \sum_{t=0}^{\infty} \prod_{s=0}^t (1+i_s)^{-1} [Y_t - w_t L_t - p_t X_t - q_t M_t - \tau_t (Y_t - w_t L_t - q_t M_t - dB_t)]$$

where, again, i_s is the interest rate in period s . The maximization is subject to $Y = F(K, L)$ and to both (1) and (4). Notice that taxable profits are equal to revenues less wage payments, maintenance costs, and depreciation allowances—but not purchases of new equipment, $p_t X_t$.

Consider, again, the relative costs and benefits of maintaining old capital versus buying new capital. If the tax authority allowed no depreciation allowances ($d = 0$), then the relative price of maintenance services to new capital is $(1-\tau)q/p$. In other words, maintenance gets a tax break, but new capital does not. In a profit-maximizing solution, the maintenance choice satisfies

$$(6) \quad (1-\tau_t)q_t/p_t = -\delta'(M_t/K_t).$$

As we raise taxes, we lower the relative price of maintenance. Thus, we expect spending on maintenance relative

to investment spending to increase. Conversely, as we lower taxes, we raise the relative price of maintenance and expect spending on it relative to investment to decrease.

If the tax authority does allow firms to subtract depreciation ($d > 0$), then the calculation of benefits to increased X is a bit more complicated. More X implies more B , more depreciation allowances, and therefore a lower tax bill. But, of course, the depreciation allowances are in the future and, hence, not worth as much to the firm as deductions in the current period. In this case, the maintenance choice satisfies

$$(7) \quad (1-\tau_t)q_t/[(1-\mu_t)p_t] = -\delta'(M_t/K_t)$$

where

$$(8) \quad \mu_t = [\mu_{t+1}(1-d) + \tau_{t+1}d]/(1+i_{t+1})$$

and where μ_t is the multiplier on constraint (4) in the firm's profit-maximization problem and captures the discounted benefits of depreciation allowances. Again, as tax rates increase (decrease), we expect spending on maintenance relative to investment spending to increase (decrease).¹

Cutting Taxes

In this section, we look at how a cut in the capital income tax rate τ will affect capital intensity (that is, the capital/labor ratio) in the representative firm model above with maintenance and in a representative firm model without maintenance. We show that under reasonable conditions, a decrease in the capital income tax rate has a larger impact on capital intensity in the model without maintenance.

Recall the profit-maximization problem above with taxes. Let λ_t and μ_t be the multipliers on the capital stock [equation (1)] and on the book value [equation (4)] constraints, respectively. To keep matters simple, we want to examine how changes in taxes affect the steady-state solution to the firm's maximization problem. Hence, we assume that prices, interest rates, and taxes are constant over time. From the necessary conditions of the firm's problem and the assumption about constant prices, we can derive the following equation that is satisfied in the steady-state solution:

$$(9) \quad 1 = (1+i)^{-1} \{ [(1-\tau)/(1-\mu)] [F_K(K/L)/p] + 1 - [\delta(M/K) - \delta'(M/K)M/K] \}$$

where $F_K(K/L)$ is the marginal product of capital (which we assume depends on K/L) and the multiplier μ is now

$$(10) \quad \mu = \beta d \tau / [1 - \beta(1-d)]$$

where $\beta = (1+i)^{-1}$.

Now let's consider the model without maintenance. We assume everything is the same in this new model except that the rate of depreciation is a constant. Let the capital depreciation rate be $\bar{\delta}$. In this model without maintenance, we can show that the following equation is satisfied in the steady-state solution:

$$(11) \quad 1 = (1+i)^{-1} \{ [(1-\tau)/(1-\mu)] [F_K(K/L)/p] + 1 - \bar{\delta} \}$$

where the multiplier μ is the same as above [in (10)].

Now let's discuss how we will compare the two models. First, regarding the parameters that the models have in common, we assume the same parameter values across the two models. Second, we choose the parameters of the $\delta(M/K)$ function so that the steady-state value of $\delta(M/K) - \delta'(M/K)M/K$ in equation (9) equals $\bar{\delta}$. By doing that, we insure that the capital/labor ratios are the same in the two models at the given initial tax rate τ .

Now let's imagine lowering the tax rate τ and observe how the steady-state capital/labor ratios change in the two models. If F_K is monotonically decreasing in K/L and if $\delta(\cdot)$ is convex (that is, $\delta' < 0$ and $\delta'' > 0$), then a decrease in the tax rate τ increases the steady-state capital stock more in the model without maintenance than it does in the model with maintenance. We can show this as follows. In (9) consider the term $H(\tau) = 1 - [\delta(M/K) - \delta'(M/K)M/K]$, where recall that M/K is a function of τ , in particular, an increasing function of τ . It is easy to show that H is an increasing function of τ . It follows, then, that in the new steady state with lower taxes, $F_K^{wm} > F_K^{wom}$, where wm denotes the model *with maintenance* and wom denotes the model *without maintenance*. Hence, $(K/L)^{wm} < (K/L)^{wom}$. Hence, the increase in capital intensity is smaller in the model with maintenance.

The intuition for the above result is straightforward. As tax rates are increased, maintenance is substituted for investment when this option is available. Hence, when this option is available, the decrease in capital intensity is smaller as we increase the tax rate. Conversely, the increase in capital intensity is also smaller as we decrease the tax rate. While we have only compared what happens to capital intensity in the two models as taxes on capital are lowered, it may well be that similar results carry over to such things as the effects on welfare of cutting capital income taxes. (See, for example, McGrattan and Schmitz 1999).

Evidence

In the previous section, we showed that if we add the activity of maintenance and repair to a standard model, we can change the quantitative answers to questions addressed with such a model. But how much will the answers change? This likely depends on the relative size of expenditures on maintenance and repair and the degree to which the activity substitutes for investment. In this section, we show that according to the existing data, the expenditures are relatively large and the activity does substitute to some extent for investment. We first discuss the definitions of maintenance and repair and investment. We then discuss where data on maintenance and repair spending can be found. Finally, we discuss the Canadian data and the much less comprehensive U.S. data.

Definitions

Because of the tax ramifications of categorizing an expenditure as either maintenance and repair or investment, there are standard definitions of maintenance and repair and investment in the accounting literature. Moreover, and not surprisingly, most of the data collected are gathered on the basis of these accounting definitions. These definitions are as follows.

Maintenance and repair expenditures are expenditures made for the purpose of keeping the stock of fixed assets or productive capacity in good working order during the

life originally intended. These include costs incurred to forestall breakdowns of equipment and structures (*maintenance*) and costs incurred to restore fixed assets to a state of good working condition after malfunctioning (*repair*).

Capital expenditures, or investment spending, are costs of all new plants and machinery and equipment which normally have a life of more than one year. Capital expenditures include purchases of new assets as well as major improvements or major alterations to existing assets.

As one can imagine, it may be hard to fit a particular expenditure into one category or the other. A firm would obviously like to categorize most of its expenditures of these types as maintenance and repair (and not investment) given that maintenance and repair can be immediately expensed, while investment must be capitalized and depreciated over time. And while firms have this incentive, the tax authorities obviously have an interest in making sure taxes are collected. Here, as in many areas of tax law, what can be treated as maintenance and repair is determined by precedent through rulings by the tax authority as it reviews the tax returns of businesses.²

Where to Find Data?

In many countries, like the United States, it is not possible from published sources to determine the extent of maintenance and repair in the aggregate. To see some of the difficulties in attempting to construct aggregate measures of maintenance and repair, consider the following.

First, when businesses maintain and repair their capital, the activity is often performed by employees; hence, there is no market transaction. Of course, some goods and services that are produced and consumed in the same business are imputed to GDP, and the value of such goods and services is recorded in the national accounting systems. (For example, restaurant meals consumed by restaurant employees are imputed to GDP.) But few such imputations are made in the accounting systems of most countries, and none is typically made for maintenance and repair.

Second, if a business purchases maintenance and repair services in the market, that is treated as an intermediate good transaction. Some intermediate good transactions are recorded in input/output tables in national accounting systems. But purchases of maintenance and repair are recorded, if at all, only for a few sectors of the economy. (For example, in the United States there are spotty data on maintenance and repair purchases in the manufacturing industry, but not much more.) Hence, it is typically impossible to determine the size of maintenance and repair from the standard national accounting systems.

In Canada, however, businesses and government organizations are directly asked about expenditures on maintenance and repair in a separate survey (the same survey in which they are asked about their investment spending). In particular, the government agency Statistics Canada has conducted an annual "Capital and Repair Expenditures" survey since 1956 which collects data on maintenance and repair expenditures and investment expenditures for all sectors of the Canadian economy. The evidence we discuss is primarily from this Canadian survey (Canada, various years). The data for the United States are much more limited.

Canada

The "Capital and Repair Expenditures" survey distinguishes three major sectors of the Canadian economy: business, government, and household. It also considers two types of assets: equipment and structures. The survey covers the maintenance and repair of both types of assets for all three sectors of the economy except the repair of household equipment. In principle, it is not hard to get some data on spending to repair household equipment since some of these transactions occur in final good markets. For example, when a household brings a car to the shop or hires a person to repair a refrigerator, both transactions are recorded as final goods. However, in this article, for Canada we use only the Canadian survey and, hence, do not consider the repair of household equipment.

The survey's questionnaire asks respondents for information on expenditures on both new and old capital. The definitions used in this survey are similar to the general definitions discussed above. Here we give a bit of the details of the questionnaire. The survey defines *capital expenditures*, what we have called *investment spending*, as gross expenditures on fixed assets for use in the operations of the organization or for lease or rent to others. With regard to these assets, respondents are asked to include on their annual survey questionnaire expenditures on

- New buildings, engineering, machinery, and equipment which normally have a life of more than one year and are charged to fixed asset accounts.
- Modifications, additions, and major renovations.
- Feasibility studies and architectural, legal, installation, and engineering fees.
- Work done by the firm's own labor force.
- Additions to work in progress.

The survey's term for spending on maintenance and repair is *noncapital maintenance and repair expenditures*. For these, respondents are asked to include expenditures on

- Gross maintenance and repair of nonresidential buildings, other structures, and machinery and equipment.
- Building maintenance, such as janitorial services, snow removal, and sanding.
- Equipment maintenance, such as oil changes and lubrication of vehicles and other machinery.
- Repair work done by the firm's own employees as well as by outside persons.

We will discuss three aspects of the data from the Canadian survey. We first discuss the size of expenditures on maintenance and repair, looking at the size relative to GDP, relative to expenditures on new physical capital, and relative to other investment activities. We then explore how maintenance and repair expenditures move relative to investment spending over the business cycle. Finally, we look at the behavior of maintenance and repair expenditures relative to investment spending in a particular industry, the Canadian iron ore industry, during a period of crisis. We show that the maintenance and repair activity is large and that it is less volatile than investment over the business cycle and during a period of crisis. We think the

Canadian evidence shows that the activities of maintenance and repair and investment are relatively close substitutes.

□ *Size*

In this section, we show that in Canada the maintenance and repair activity is large, relative to GDP and relative to several investment activities, in particular, spending on new physical capital.

In Table 1, we present the expenditures in seven countries on five activities: total maintenance and repair, repair of household structures, research and development (R&D), education, and investment in physical capital—all as a percentage of each country's GDP. We construct averages over the period 1981–93, which is the period for which the most data are available.

In the first column of data, we report total maintenance and repair expenditures, which are available only for Canada. In Canada, total maintenance and repair expenditures have averaged 5.7 percent of GDP over the period from 1981 to 1993. The average is 6.1 percent if we use data back to 1961. If we were to include some measure of expenditures for the repair of household equipment, these figures would be higher.

In the second data column of Table 1, we report maintenance and repair expenditures for household structures. As we discuss below, the only survey on maintenance and repair in the United States deals with expenditures for household structures (U.S. Department of Commerce, various years). The United States and Canada spend the same percentage of GDP on the repair of household structures: 0.7 percent.

In comparison to total maintenance and repair, R&D expenditures in Canada, reported in the third data column of Table 1, have been one-fourth as large on average, or 1.4 percent of GDP. In Table 1, we also report R&D expenditures for six other industrial countries. Canada is at the low end of R&D spending, but only by a percentage point or so.

In the fourth data column of Table 1, we report current public spending on education (given to public and private institutions). Public spending on education in Canada is slightly larger than spending on maintenance and repair, 6.8 percent compared to 5.7 percent. Canada is at the high end of public spending on education.

In the final column of Table 1, we report spending on new physical capital. This is spending on gross fixed capital formation as a percentage of GDP, taken from the national account statistics of the Organisation for Economic Co-operation and Development. Average investment in new physical capital ranges from 16 percent in the United States to 30 percent in Japan, with most of the countries around 20 percent.

In Canada over this period, then, maintenance and repair averaged 28 percent of new investment (5.7 percent divided by 20.6 percent). We now look further at maintenance and repair relative to investment.

In Table 2, we compare Canadian maintenance and repair expenditures to spending on new physical capital by asset and by economic sector. Over the period 1956–93, maintenance and repair expenditures were 30.4 percent of spending on new physical capital (which is slightly higher than the 28 percent during the 1981–93 period in Table 1). By type of asset, spending on maintenance and repair of equipment was much larger than spending on maintenance

and repair of structures relative to new spending on each. Maintenance and repair of equipment was 48 percent of spending on new equipment. Maintenance and repair of structures was 21 percent of spending on new structures. Looking by major sector of the economy, we see this same pattern, though it is less pronounced in the government sector.

In Chart 2, we plot the percentages that maintenance and repair expenditures on physical capital have been of spending on new physical capital annually during 1956–93. We also plot these percentages by type of asset: equipment and structures. None of these time series display any noticeable upward or downward trend over the 1956–93 period. And as we saw in Table 2, maintenance and repair expenditures have been relatively larger for equipment than for structures.

In Table 3, we compare maintenance and repair expenditures to spending on new physical capital by industry within the business sector. In the first column of data, we report the average share of the total business sector's output that came from each industry over the period 1961–93. So, for example, the largest industry is manufacturing, which had a product equal to one-quarter of the business sector product. In the second data column, we report capital expenditures as a percentage of gross product for each industry. Notice that this percentage varies a lot across industries. The final column shows maintenance and repair expenditures as a percentage of spending on new physical capital for each industry. In one industry—namely, forestry—spending on maintenance and repair exceeds spending on new structures and equipment. In the construction and manufacturing industries, maintenance and repair expenditures are at least half of new investment expenditures. When we aggregate the business sector, we find that maintenance and repair expenditures are still quite a large percentage of spending on new physical capital: about 34 percent.

□ *Substitutability*

The maintenance and repair activity is large relative to investment. But to what extent does it substitute for investment? With establishment level data from Canada, it should be possible to estimate the extent of substitutability with precision. Here we simply show that the activities of maintenance and repair and investment respond differently to some economic events—business cycles and crises—which suggests a good deal of substitutability.

We start by looking at normal business cycle movements in Canadian GDP and maintenance and repair and investment expenditures. In Chart 3, we display the volatility of maintenance and repair expenditures, spending on new physical capital (investment), and GDP, using 1961–93 data filtered with the Hodrick-Prescott filter. In other words, we detrend each series y (all in current dollars) by taking logs and subtracting the trend \hat{y} that solves

$$(12) \quad \min_{\{\hat{y}_t\}} \sum_{t=1}^T \{y_t - \hat{y}_t\}^2 + \lambda \sum_{t=2}^{T-1} \{(\hat{y}_{t+1} - \hat{y}_t) - (\hat{y}_t - \hat{y}_{t-1})\}^2.$$

In Chart 3, we plot these three series (where we use $\lambda = 100$ in the above formula).

Clearly, spending on maintenance and repair is much less volatile than spending on new capital. The standard deviation of maintenance and repair expenditures is 61 percent of that for spending on new capital. If we look

within asset categories, we find differences between the types of assets. For structures, the standard deviation of maintenance and repair expenditures is 77 percent of that for spending on new structures. For equipment, the standard deviation of maintenance and repair expenditures is only 51 percent of that for spending on new equipment.

Notice also in Chart 3 that both the maintenance and repair and investment activities are procyclical and both are more volatile than GDP. At the annual frequency, the standard deviation of spending on new physical capital is 2.42 times that of GDP, and the correlation with GDP is 0.80. The standard deviation of maintenance and repair expenditures is 1.47 times that of GDP, and the correlation with GDP is 0.89.

There are many studies that focus on the volatility of investment in the manufacturing industry. Hence, we think it is of interest to compare the volatility of maintenance and repair and investment in manufacturing. In Chart 4, we repeat the exercise of Chart 3 for Canadian manufacturing. In manufacturing, the standard deviation of maintenance and repair expenditures is only about 38 percent of that for spending on new capital.

We next consider the movements of maintenance and repair and investment during a period of crisis. The Canadian iron ore industry faced much more than a typical downturn in the 1980s—its output fell on the order of 50 percent in a year, and its future was highly uncertain. (See Schmitz 1998 and Galton and Schmitz 1999.) In this industry, the Canadian survey shows, equipment investment fell to nearly zero during the period of crisis, while the industry still spent significant amounts on maintenance and repair of equipment. (Maintenance and repair expenditures fell about the same amount as output, that is, in half.) These patterns can be seen in Chart 5.

United States

Our reason for focusing on the Canadian survey is simple: there is no survey in the United States that is comparable to the Canadian survey. In particular, it is not possible to determine for the United States the size of maintenance and repair in the aggregate. However, some spotty data on U.S. maintenance and repair expenditures do exist. We briefly discuss those data in this section. We show that the spotty U.S. data tell the same story as the Canadian data—maintenance and repair expenditures are large.

First, recall that the Canadian survey covers three sectors (business, government, and household) and two assets (equipment and structures). In the United States, the only relevant major survey covers one sector (household) and one asset (structures). (An early attempt to cover all structures was dropped; see U.S. Department of Commerce 1975, pp. 612–13, sec. N 61.) This survey is part of the consumer expenditure surveys conducted by the Bureau of the Census of the U.S. Department of Commerce. The survey results are published as the series *expenditures for residential improvements and repairs* (C-50). The expenditures for the repair of household structures in the United States are similar in size to those in Canada. Recall Table 1, where we showed that in both countries, such expenditures averaged 0.7 percent of GDP.

While the only sector and asset for which there are comprehensive data in the United States are household structures, there is some information on the maintenance and repair of equipment and structures in the manufactur-

ing industry. However, the only information is for purchases of those services. (It does not include maintenance and repair performed in-house.) In 1982, for example, maintenance and repair purchases were about 25 percent of investment in the U.S. manufacturing industry. (See U.S. Department of Commerce 1982.) Recall that in Canada, the 1961–93 average was about 50 percent in manufacturing (which includes both purchases and in-house maintenance and repair).

For the United States, we also have some data for industries during a crisis. For the United States during the Great Depression, Fabricant's (1938) estimates show that expenditures on maintenance and repair were about the same size as expenditures on new plant and equipment in the manufacturing and mining industries. Fabricant estimates that in 1934 manufacturing and mining firms spent \$1.50 billion on maintenance and repair. In that same year, business expenditures on new plant and equipment were \$1.46 billion. (See U.S. President 1952.) Recall again that in the Canadian manufacturing industry, spending on maintenance and repair during 1961–93, which was not a crisis period, was only about one-half of spending on new investment.

Concluding Remarks

In this article, we have shown that the activity of maintaining and repairing physical capital is too big for economists to ignore. We first showed that, under reasonable conditions, reductions in the capital income tax rate would lead to smaller increases in a firm's capital intensity in a model in which capital is maintained and repaired than in a standard model without that activity. However, this was simply a comparative statics exercise. In order to determine whether the difference between the two types of models might be large, we turned to the evidence on maintenance and repair. We examined data from an economywide survey in Canada which showed that maintenance and repair expenditures are large relative to investment expenditures and that the maintenance and repair activity is to some degree a substitute for investment. This evidence suggests that the difference between the tax cut effects predicted by standard models and by those including maintenance and repair may be quite large. Thus, work to determine the actual size of that difference would seem to be a productive endeavor.

There are many other uses for this Canadian survey data. For example, the data would be useful to further examine studies of particular industries that argue that significant movements in productivity in the industries were due to changes in the amount of maintenance and repair of capital in those industries. Gordon (1992, abstract), for instance, argues that slowdowns in productivity in the U.S. electric utility industry since the late 1960s have been due in part to "unanticipated maintenance problems requiring substantial additions of maintenance employees." Most of the evidence for this conclusion was derived from interviews. Similarly, Aizcorbe and Kozicki (1995) argue that observed procyclicality of productivity in the U.S. automotive assembly industry during 1978–84 was driven in large part by the fact that when plants periodically shut down (and hence had zero output), they continued to employ workers (in nonproduction tasks). Based on interviews, Aizcorbe and Kozicki suggest that a major task undertaken during a shutdown was likely to be maintenance of the

plant and equipment. With the Canadian survey data, the types of arguments made in these two studies could be buttressed—or refuted—by the actual expenditures on maintenance and repair in these industries.

Beyond the analysis of particular industries, of course, there is the issue of measuring an entire economy's capital stock. Today, as far as we know, maintenance and repair data are not used in the construction of any nation's capital stock, even Canada's. (See Canada, undated.) Incorporating this activity into a national accounting system would lead to better estimates of the nation's capital stock. And that would help economists better analyze a myriad of economic issues.

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¹In the model above, there is one type of capital good, and tax policy influences the extent to which capital is maintained. Goolsbee (1998) argues that tax policy also influences the type of capital goods purchased, where types vary by the extent they must be maintained.

²As an illustration of potential ambiguities, note that in *Libby & Blouin, Ltd.*, Dec. 1637 (acq.), "it has been held that expenses for small parts of a large machine, made in order to keep the machine in efficient working condition, were deductible expenses and not capital expenditures even though they may have a life of two or three years" (CCH 1999, p. 22,182).

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Chart 1
How Maintenance Affects Capital's
Depreciation Rate in the Model

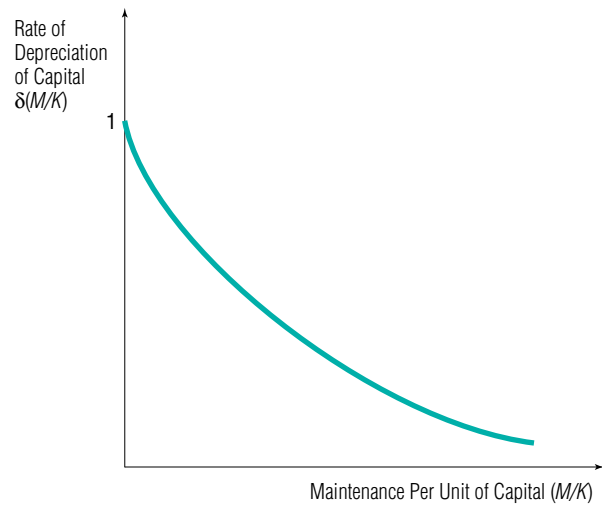
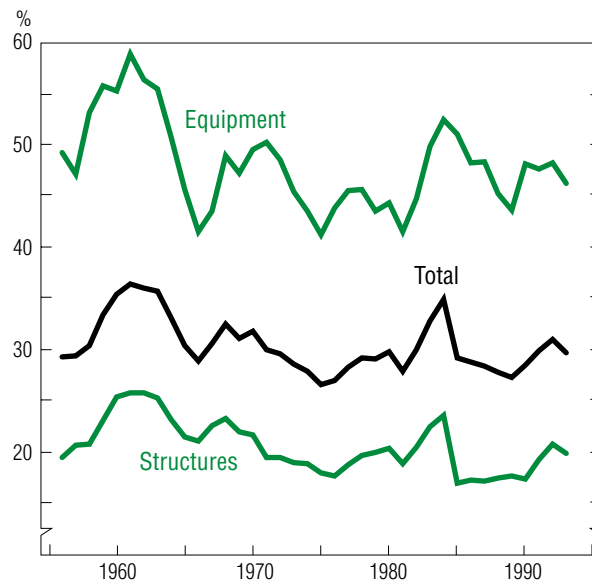


Chart 2

No Apparent Trends

Canada's Spending on Maintenance and Repair
as a Percentage of Spending on New Physical Capital
by Type of Asset

Annually, 1956–93



Source: Statistics Canada

Charts 3–4

Volatility: Maintenance and Repair
vs. New Investment and GDP

Percentage Deviations From Trend* of Canada's GDP
and Spending on Maintenance and Repair and New Physical Capital
Annually, 1961–93

Chart 3 In All Sectors

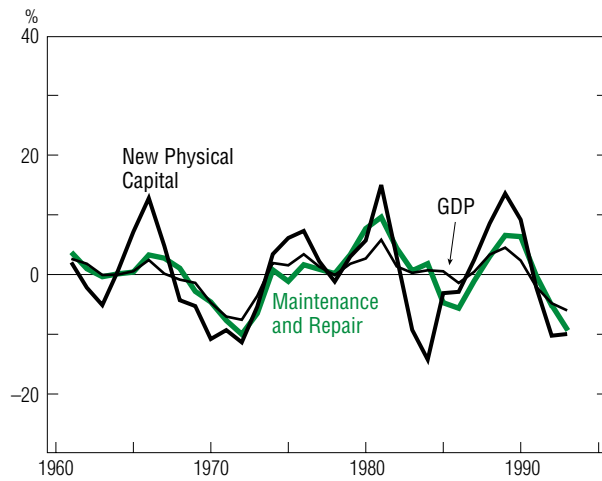
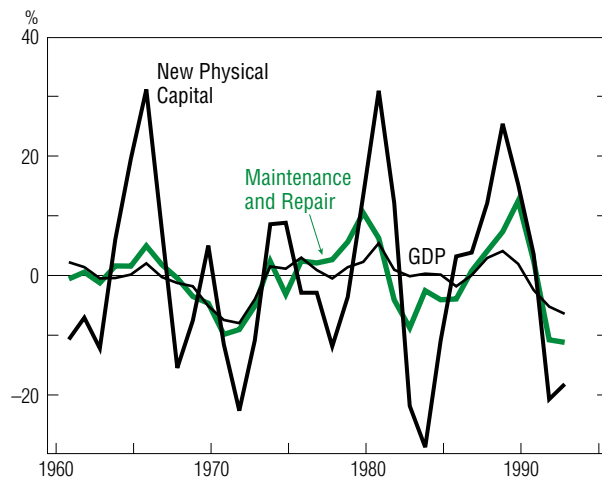


Chart 4 In the Manufacturing Industry



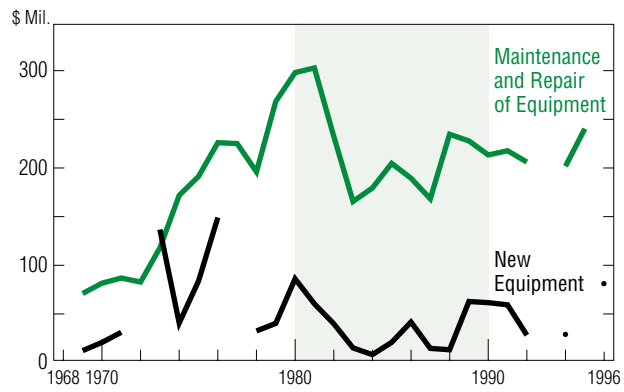
*The data have been logged and filtered with the Hodrick-Prescott filter
(detrended as described in the text).
Source: Statistics Canada

Chart 5

One Industry in a Period of Crisis

Spending on Maintenance and Repair of Equipment
and on New Equipment in the Canadian Iron Ore Industry

Annually, 1969–96*



*Gaps in the plotted lines are due to unavailable data.
Source: Statistics Canada

Size

Table 1 Maintenance and Repair and Other Activities vs. GDP

Spending on Selected Activities as a Percentage of GDP, in Seven Countries
Averages, 1981–93

Country	Type of Activity as a % of Each Country's GDP				
	Total Maintenance and Repair	Repair of Household Structures	Research and Development	Education	New Physical Capital
Canada	5.7%	.7%	1.4%	6.8%	20.6%
France	—	—	2.3	5.2	20.3
Germany	—	—	2.6	3.9	20.2
Italy	—	—	1.1	4.2	20.4
Japan	—	—	2.6	4.3	29.6
United Kingdom	—	—	2.2	4.8	17.2
United States	—	.7	2.6	5.5	15.6

Sources: Statistics Canada, U.S. Department of Commerce,
National Science Foundation, United Nations,
Organisation for Economic Co-operation and Development

Tables 2–3 Maintenance and Repair vs. New Investment

Canadian Maintenance and Repair Spending
as a Percentage of Spending on New Physical Capital

Table 2 By Sector and Asset

Averages, 1956–93

Sector	% of Investment Spending for Each Type of Asset		
	Total	Equipment	Structures
Business	34.3	48.7	19.2
Government	25.8	34.0	25.0
Household	—	—	22.4
Total	30.4%	48.0%	20.6%

Table 3 By Industry in the Business Sector

Averages, 1961–93

Industry	Each Industry's		
	Product as % of Sector Product	Investment as % of Industry Product	Maintenance and Repair as % of Industry Investment
Manufacturing	25.0	16.3	50.6
Finance, Insurance, and Real Estate	15.6	8.7	10.2
Trade	13.9	5.7	25.7
Utilities	12.5	42.1	37.4
Business Services	12.4	24.9	15.2
Construction	8.8	5.0	75.3
Mining	6.7	33.1	32.0
Agriculture	4.1	36.2	40.0
Forestry	1.0	11.3	110.1
Total	100.0%	18.7%	34.2%

Source: Statistics Canada
