



WP/20/77

IMF Working Paper

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Authorized for distribution by Ruud de Mooij

May 2020

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Abstract

The paper provides estimates of the long-run, tax-adjusted, user cost elasticity of capital (UCE) in a small open economy, exploiting three sources of variation in Canadian tax policy: across provinces, industries, and years. Estimates of the UCE with Canadian data are less prone to the endogeneity problems arising from the effects of tax policy changes on the interest rate or on the price of capital equipment. Reductions in the federal corporate income tax rate during the early 2000s for service industries but not for manufacturing, which already benefited from a preferential tax rate, contribute to the identification of the UCE. To capture the long-run relationship between the capital stock and the user cost of capital, an error correction model (ECM) is estimated. Supplementary results are obtained from a distributed lag model in first differences (DLM). With the ECM, our baseline UCE for machinery and equipment (M&E) is -1.312. The corresponding semi-elasticity of the stock of M&E with respect to the METR is about -0.2, suggesting, for example, that a 5 percentage point reduction in the METR, say from 15 to 10 percent, would in the long run generate an increase of 1.0 percent in the stock of M&E. The UCE for non-residential construction is statistically insignificantly different from zero.

JEL Classification Numbers: H25, H32

Keywords: Capital Taxation, User Cost of Capital Elasticity, Marginal Effective Tax Rate

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I. INTRODUCTION

During the 2012 Canadian federal election campaign, the Finance Minister summed up his belief about the benefits of corporate income tax cuts with the statement: “Low taxes are encouraging businesses to invest more in the Canadian economy, which is stimulating job creation and economic growth.”(CBCNews, 2011). Similar arguments were made in the U.S. on the tax cuts of the Trump administration. Is the belief justified? This paper contributes to the policy debate by estimating the long-run user cost elasticity of demand for capital (UCE) using an error correction model (ECM) applied to Canadian panel data, that varies by industry, by year, and by province.¹

A fundamental difficulty of estimating the UCE is the identification problem that arises from investment demand movements over the business cycle. Schaller and Voia (2017) argue that cointegration techniques, such as the ECM, which capture long-run relationships, can reduce simultaneity bias by exploiting persistent shifts in the supply curve, due to technological change and tax reforms. Canadian data has some attractive features for identifying the UCE. The real interest rate and the price of machinery are largely determined in the U.S. market, since Canada is a small open economy and imports most of its machinery from the U.S., as argued by Schaller (2006).² This observation helps to address the usual concerns about the potential endogeneity of the user cost of capital that arises in large open economies (Goolsbee, 2000), which have been the focus of most previous UCE studies.³

Starting in 2001, the federal government significantly reduced the corporate income tax (CIT) rate. The general federal CIT rate fell from 28 percent in 2000 to 21 percent in 2004 with the government’s “Five Year Reduction Plan” and eventually down to 15 percent by 2012.⁴ The 2001–2004 tax cuts stemmed from a critique of the structure of taxation by the *Report of the Technical Committee on Business Taxation* (1998) and from the announcement of a policy objective in *The Budget Plan 2000* to make Canada’s business tax system internationally competitive. Taking the federal lead, some provinces also cut their corporate tax rates. The federal and provincial tax reductions were, therefore, motivated by long-term considerations and unlikely to be responses to short-run aggregate demand conditions.⁵ Different than the Schaller (2006) study, which ends with 1999, our analysis covers these more recent tax reforms.

¹ The UCE is the percentage change in the net capital stock for a 1 percent change in the user cost, where the user cost refers to the marginal cost of holding an incremental unit of capital for one period, inclusive of all business-related taxes.

² Canada is often cited as a prototypical small open economy. See, e.g., Guerron-Quintana (2013).

³ Coulibaly and Millar (2011) exploit the fact that the small open economy assumption for South Africa was temporarily violated during the country’s embargo period to show that UCE estimates tend to be biased downward in closed economies.

⁴ The federal government announced its Five Year Reduction plan in the February 2000 budget, beginning with a 1 percentage point reduction in January 2001. The October 2000 budget update announced the further reductions of 2 percentage points in each of the following three years. The rate cuts did not apply to manufacturing and processing activities, because these already benefited from a preferential CIT rate.

⁵ This echoes Schaller’s (2006) observation that, “the last major reorganization of corporate tax rates and the ITC in Canada closely followed the 1986 U.S. tax reform.”

Additionally, we exploit variations in tax policies and capital stocks across provinces and industries to improve identification of the UCE. The number of cross-sectional observations on industry-province pairs makes it feasible to use a system-GMM method to estimate a dynamic panel model for the period 1997–2013.⁶ System-GMM is designed to deal with situations in which the dependent variable may depend on its lagged value, where there are fixed effects, and where some explanatory variables may be endogenous. These circumstances are relevant for capital stocks, which would render the alternative of simple ordinary least squares (OLS) regressions biased and inconsistent. The small open economy assumption applies also to the individual provinces in Canada, which should dampen inter-provincial tax competition for productive investment. In a small open economy, the supply of capital financing is highly elastic, implying that all profitable investment opportunities should be realized in each jurisdiction and industry. As Mintz and Smart (2004) note, “tax setting by provincial governments is apt to be governed principally by competition for financial flows rather than for productive investment.” Consequently, competition between provinces for the *taxable income* base should not bias our UCE estimates.⁷ It is also noteworthy that, in Canada, groups of corporate affiliates are not permitted to consolidate income for tax purposes. Only multijurisdictional firms that do not operate separate corporate subsidiaries in each province (representing 35 percent of corporate income between 2005 and 2008) must allocate total income according to a statutory formula based on the distribution of sales and payroll among provinces.⁸ This is quite unlike the United States, where consolidation in corporate groups is required and most firms must use apportionment. Hence, the potential effect of apportionment on the UCE estimates is likely to be much less pronounced using Canadian provincial data.

In contrast to our use of panel data, Schaller (2006) applies cointegration techniques to aggregate Canadian time series.⁹ To construct the panel data, we make use of the detailed provincial and federal tax information embodied in the marginal effective tax rate (METR) figures

⁶ Given 7 industries and 10 provinces in our data, we have a cross-section of 70 industry-province pairs and 17 years of observations. A rule of thumb is that the number of cross-sections must exceed the number of instruments used in system-GMM. If the data were aggregated, say, to the national level, varying only by industry and year, the number of cross-sections would be cut to 7, rendering it impossible to use system-GMM, even after minimizing the instrument count by collapsing the instrument matrix and limiting the lag depth (Roodman, 2009a).

⁷ Mintz and Smart (2004) find evidence of income shifting for tax purposes between corporate affiliates in Canada, which could motivate provincial governments to lower their statutory tax rates to attract accounting profits. While the availability of corporate tax planning at both the national and international levels could reduce the sensitivity of investment to the tax rates of a given province, this consideration is part of the UCE and not a source of endogeneity of the regressors. The potential endogeneity issue can be conceived as follows. Suppose there are two provinces, A and B, competing for a *fixed* stock of productive capital through a race to the bottom in tax rates. If A reduces its tax rate in period t , B may experience a negative shock to its capital stock in a subsequent period and respond by cutting its own tax rate. In this case, B’s tax rate would be correlated with the error term in the capital stock regression. However, as we have noted, the supply of productive capital is not fixed in a small open economy.

⁸ See Department of Finance Canada (2010).

⁹ See also ab Iowerth and Danforth (2005), who apply cointegration techniques to components of machinery and equipment in Canada. The only other study that estimates the UCE with Canadian data is by Parsons (2008). He obtains a UCE of -0.7 using a difference-in-differences approach on the 2001–2004 tax reforms.

calculated annually by Duanji Chen and Jack Mintz.¹⁰ As we show, the user cost of capital can be expressed as a function of the METR and non-tax variables. This allows us not only to use the Chen and Mintz METR data to calculate the user costs, but also to supplement the UCE with a semi-elasticity of capital with respect to the METR itself. Given the intuitive appeal of the METR as a tax rate, the semi-elasticity provides an effective way to communicate the impact of business taxes on capital formation. See McKenzie (2016) for a recent review of METRs and a discussion of the theory.

Most previous estimates of the UCE have been based on large open economies, such as the U.S. and major European countries. These include Auerbach and Hassett (1991), Cummins and Hassett (1992), Cummins, Hubbard, and Hassett (1994, 1996), Chirinko, Fazzari, and Meyer (2002), Tevlin and Whelan (2003) and Schaller and Voia (2017).¹¹ An alternative to the ECM is a distributed lag model (DLM) in first differences. Taking first differences deals with the potential problems posed by non-stationarity (Chirinko, Fazzari and Meyer, 1999). However, Dwenger (2014) argues that a DLM in first differences omits important long-run information, resulting in an underestimate of the UCE. She points out, for example, that the DLM does not distinguish between permanent and temporary shocks in the UCC. Since firms are presumably more sensitive to permanent shocks, given the costs of adjustment, the UCE estimated from the DLM is likely to be smaller in absolute value than the one estimated within the long-run equilibrium stochastic relationship embodied in the ECM.¹² She obtains a UCE close to -1 with an ECM, but a much lower magnitude using the DLM of Chirinko, Fazzari and Meyer (1999). We also provide estimates of a DLM with our data and corroborate Dwenger's finding for Germany.

The empirical value of the UCE remains uncertain. The review by Hassett and Hubbard (2002) favors -1 , while Chirinko (2008) concludes that the weight of the evidence indicates a UCE in the range of -0.4 to -0.6 . Schaller (2006) found a UCE of -1.6 for machinery and equipment (M&E), while his UCE estimates for non-residential construction (NRC) are indistinguishable from zero. We also obtain statistically insignificant results for NRC. Later, we discuss several reasons why estimating the UCE for NRC poses unique challenges, that may explain the puzzling finding. Our baseline estimates of the UCE for M&E range from -1.078 to -1.312 . Assuming an METR for M&E of 11 percent (the most current value in the sample), the semi-elasticity of the stock of M&E with respect to the METR is about -0.2 . The value of the semi-elasticity suggests, for example, that a 5 percentage point reduction in the METR, say from 15 to 10 percent, would in the long run generate an increase of 1.0 percent in the

¹⁰ See, e.g., Chen and Mintz, 2015. We are grateful to Jack Mintz, Duanjie Chen and V. Balaji Venkatachalam at the University of Calgary's School of Public Policy for sharing their METR figures at the level of disaggregation required for our analysis for the period 2007 to 2013. For the earlier period of 1997 to 2006, we calculated the disaggregated METRs by adapting the pre-2007 METR model of Chen and Mintz.

¹¹ Some studies refer to the elasticity of "investment," while others refer to the elasticity of the "capital stock." A typically used dependent variable is I_t/K_{t-1} where I_t is gross investment and K_{t-1} is the lagged value of the capital stock. When this variable is regressed against the percentage change in the user cost (rather than its level), the coefficient is equivalent to a long-run elasticity of the capital stock, as Chirinko, Fazzari, and Meyer (1999) show.

¹² Some temporary tax incentives may have important intertemporal effects on investment in the short term, but not necessarily on the level of the capital stock in the longer run.

stock of M&E. Overall, the results appear to justify the belief of the Finance Minister in the run up to the 2012 election, that physical capital investment, particularly machinery and equipment, is sensitive to business tax rates.

The remainder of the paper is organized as follows. Section 2 reviews the concepts of the user cost of capital and the marginal effective tax rate, and the theory of investment. Section 3 describes the data and tests for nonstationarity and cointegration. Section 4 contains the empirical results. Section 5 concludes. An appendix gives a brief description of the DLM model and contains the empirical results for NRC.

II. THEORY

A. User Cost of Capital

According to the neoclassical theory of investment in a small open economy, firms add to their capital stock until the rate of return is just sufficient to pay corporate taxes and a competitive net-of-tax return to international investors.¹³ Thus the user cost of capital equals the equilibrium gross-of-tax rate of return. The user cost of capital C is given by¹⁴

$$C = q \frac{(1+t_s)(r_f + \delta) [(1-\phi) + \tau(1-u)/(\delta + r_f + \pi)]}{1-u} \quad (1)$$

where $q = p_K/p$ is the relative price of the capital input p_K to the output price p , δ is the economic depreciation rate, r_f is the real cost of corporate funds (i.e., net of inflation), t_s is the provincial sales tax on capital goods wherever this is applicable, τ is a capital-based tax rate,¹⁵ u is the statutory corporate income tax rate,¹⁶ and ϕ is the reduction in the effective price of capital arising from the tax shield provided by capital cost allowances and investment

¹³ The neoclassical model of investment behavior and the concept of the user cost of capital originate with Jorgenson (1963).

¹⁴ To avoid clutter in the exposition, we shall omit the subscripts for province, industry, and year, until they are needed.

¹⁵ Federal and provincial governments have levied a tax on the capital employed (essentially, paid-up equity and debt) by large corporations (i.e., with assets in excess of \$10 million). The federal tax was eliminated in 2006, except for financial and insurance corporations; some provinces continue to apply a general capital tax. Denoting the federal capital tax rate by τ_f , the provincial capital tax rate by τ_p , the combined federal-provincial capital tax rate is $\tau = \tau_f + \tau_p$. Thus, $\tau/(\delta + r_f + \pi)$ is the present value of the federal and provincial capital taxes that arise due to the purchase of an incremental unit of capital; the term is multiplied by $(1-u)$ to reflect the fact that capital taxes are deductible for CIT purposes (though limited to the value of the surtax in the case of federal tax).

¹⁶ u is the combined federal-provincial statutory CIT rate, including the federal surtax. Letting u_f denote the federal CIT rate, u_p the provincial CIT rate, and s_f the federal surtax rate, then $u = u_f(1 + s_f) + u_p$. An archaic detail of the Canadian system is that the federal statutory CIT rate of, say 28 percent in 2000, consists of the so-called basic federal CIT rate of 38 percent net of the federal tax abatement rate, fixed at 10 percent since 1967, which reduces the basic federal rate so that the provinces can apply their own CIT rates to taxable income.

tax credits. If the rate of tax depreciation is α under a declining-balance method, then

$$\phi = uZ + \kappa \quad (2)$$

$$Z = (1 - \kappa) \times \frac{\alpha(1 + r_f + \pi)}{(\alpha + r_f + \pi)} \quad (3)$$

with κ denoting an investment tax credit rate (combining federal and provincial tax credits) and Z is the present value of capital cost allowances on one dollar of capital.¹⁷ The expression for r_f recognizes that the firm's interest on debt is tax deductible and is given by

$$r_f = \beta i(1 - u) + (1 - \beta)\eta - \pi \quad (4)$$

where β is the proportion of debt in the firm's capital structure, i is the nominal interest rate on debt, η is the required nominal return on equity, and π is the inflation rate.

The capital stock (at constant prices) used for the production of goods and services in period t is measured as the end-of-year net stock of capital in period $t - 1$. Net capital accumulates according to the equation

$$K_{t+1} = (1 - \delta)K_t + I_t \quad (5)$$

where I_t is gross investment (at constant prices) during year t .

B. Marginal Effective Tax Rate

The expression for the user cost of capital can be rewritten in terms of the METR. For this purpose, define C^n as the “net-of-depreciation user cost of capital” by subtracting $q\delta$ from (1) (Fabling et al., 2013):

$$C^n = C - q\delta \quad (6)$$

The commonly used definition of the marginal effective tax rate (METR) is the proportionate tax wedge between the net-of-depreciation user cost and the net-of-tax return received by investors:

$$METR = (C^n - qr^*)/C^n \quad (7)$$

where $r^* = \beta i + (1 - \beta)\eta - \pi$ is the investors' required net-of-tax real rate of return on corporate capital. For a small open economy, r^* is the “world” real net rate of return of the financial stakeholders.¹⁸

¹⁷ This formulation for Z assumes that the investment takes place at the end of the year. If the investment occurs at the start of the year, then $Z = \frac{\alpha}{(\alpha + r_f + \pi)}$. The half-year rule is ignored for simplicity.

¹⁸ In the METR model, the values of i and η are based on an assumed real interest rate on debt, an arbitrage equation to determine the implied rate of return on equity, and the average personal income tax rates on interest, dividends, and capital gains in the G-7 countries.

The relationship between the user cost of capital and METR can be derived by substituting for C^n in (7) using (6), adding and subtracting qr^* , and then rearranging terms to obtain

$$C = q(r^* + \delta) + qr^* \left(\frac{METR}{1 - METR} \right) \quad (8)$$

The first term on the right side of (8) is the cost of capital without taxes while the second term is the tax wedge between the net user cost of capital and the required return of investors on a marginal unit of capital. In the absence of distortionary taxes, $METR = 0$ and $C = q(r^* + \delta)$. Equation (8) is an identity that enables us to make use of the detailed METR data of Duanjie Chen and Jack Mintz to construct the tax-adjusted user cost of capital. We allow qr^* to be time-varying in the first term in (8) to capture trends in the real interest rate and the relative price of capital. However, the value of qr^* is held fixed at 0.0349 *within* the construction of the METR data made available to us. Hence, the METR varies only due to changes in tax legislation, which could introduce some measurement error in the user cost of capital variable used in our empirical work, because it ignores changes in the present value of depreciation allowances arising from changes in the interest rate. We expect the error to be small, at least in the case of M&E, where asset lives are short. The depreciation rate δ is constant over time but varies by type of capital, by industry, and by province.¹⁹ It will be useful later to note the percentage change in the user cost with respect to a small change in the METR. Letting $c \equiv \ln C$, it equals

$$\frac{dc}{dMETR} = \frac{1}{1 - METR} \cdot \frac{1}{1 + (1 - METR)(\delta/r^*)} \quad (9)$$

C. Dynamic Specifications

Suppose that the desired level of the capital stock, K^* , is a positive function of the desired output, Y , and an inverse function of the user cost of capital, C , of the form

$$K^* = \gamma Y^\zeta C^{-UCE} \quad (10)$$

where γ , ζ , and UCE are parameters. Equation (10) conforms with Agenor's (2004) "eclectic" theory, in which the desired capital stock depends on an accelerator component and the user cost of capital. Equation (10) can also be derived from a partial equilibrium analysis of the first-order conditions for a static profit-maximization problem of a firm with a CES production function, as in Dwenger (2014). In this case, it is assumed that the influence of wages on the demand for capital is transmitted exclusively by the level of output (Gould and Waud, 1973), or the desired output level is taken as fixed when the optimal amount of the capital stock is determined (Jorgenson, 1963). The doubtfulness of these assumptions is perhaps attenuated by using aggregate data (varying by sector and province), where GDP produces an accelerator effect on the stock of capital (Girardi, 2017).

¹⁹ The average depreciation rate will vary by industry and province because of the different compositions of the capital stock.

Since it generally takes time for firms to implement their currently desired capital stocks, a theory of capital adjustment is used to generate a dynamic model. We posit a general autoregressive distributed lag model in levels and apply to it the Bewley transformation (Bewley, 1979) to obtain an error-correction model.²⁰

The Bewley-transformed ECM can be written as:²¹

$$k_{i,j,t} = \psi_0 - \psi_1 \Delta k_{i,j,t} + \psi_2 y_{i,j,t} - \psi_3 c_{i,j,t} - \sum_{h=0}^{H_y-1} \psi_{4h} \Delta y_{i,j,t-h} + \sum_{h=0}^{H_c-1} \psi_{5h} \Delta c_{i,j,t-h} + v_{i,j,t} \quad (11)$$

where $x_{i,j,t} \equiv \ln X_{i,j,t}$ for province i , industry j and year t , while $\Delta x_{i,j,t-h} = x_{i,j,t-h} - x_{i,j,t-h-1}$ expresses the variables in terms of growth rates and $v_{i,j,t}$ is an error term that is the sum of orthogonal components: industry-province fixed effects, $\mu_{i,j}$, year fixed effects, λ_t , and idiosyncratic disturbances, $\varepsilon_{i,j,t}$.

An attractive feature of the Bewley transformation is that the UCE is estimated directly as the coefficient on the level of the user cost variable in (11). The UCE and the METR semi-

²⁰ The general autoregressive distributed lag specification is an ad hoc way of accounting for delivery lags and not derived from an underlying capital adjustment model (Gould and Waud, 1973). However, the well-known partial adjustment model of the capital stock is a special case of it. It can be written (for a given province and industry) as $K_t = K_t^{*1-\rho} K_{t-1}^\rho$ (Davidson and MacKinnon, 1993: 682). Taking logs and substituting for K_t^* using (10) gives $k_t = (1-\rho) \ln \gamma + \rho k_{t-1} + (1-\rho) \zeta y_t - (1-\rho) UCE c_t$.

²¹ Equation (11) is derived as follows. For simplicity of exposition, suppose that k_t has only one explanatory variable, x , and that it has two lags. Then the autoregressive distributed lag model (in levels) can be written as

$$(k_t - \rho k_{t-1}) = \gamma + \beta_0 x_t + \beta_1 x_{t-1} + \beta_2 x_{t-2} + \varepsilon_t$$

Furthermore,

$$\begin{aligned} \beta_0 x_t + \beta_1 x_{t-1} + \beta_2 x_{t-2} &= (\beta_0 + \beta_1 + \beta_2) x_t \\ &\quad - (\beta_1 + \beta_2) \Delta x_t - \beta_2 \Delta x_{t-1} \end{aligned}$$

Note that

$$k_t - \rho k_{t-1} = (1-\rho) k_t + \rho \Delta k_t$$

Using the last equation to substitute for the left-hand side of the first equation, and the middle equation to substitute for the right-hand side of the first equation, then rearranging terms and dividing through by $1-\rho$, yields the Bewley-transformed ECM:

$$\begin{aligned} k_t &= \frac{\gamma}{1-\rho} - \frac{\rho}{1-\rho} \Delta k_t + \frac{(\beta_0 + \beta_1 + \beta_2)}{1-\rho} x_t \\ &\quad - \frac{(\beta_1 + \beta_2)}{1-\rho} \Delta x_t - \frac{\beta_2}{1-\rho} \Delta x_{t-1} + \frac{\varepsilon_t}{1-\rho}. \end{aligned}$$

elasticity of capital (MSE) are defined in this notation, respectively, by

$$UCE = \frac{dk_{i,j}^*}{dc_{i,j,t}} = -\psi_3, \quad \text{for all } i, j, t \quad (12)$$

$$MSE = -\psi_3 \times \frac{dc_{i,j,t}}{dMETR_{i,j,t}} \quad (13)$$

where k^* in (12) represents the long-run equilibrium value of capital (in logs), i.e., $k^* = k_t = k_{t-1}$. The differenced terms, Δy and Δc , capture the process of adjustment to the long-run equilibrium.

III. DATA AND DEFINITIONS

A. Variations in Capital Stocks and METRs

The panel data used in the empirical analysis has three dimensions: across industries and provinces, and over time. In particular, the analysis focuses on the 10 provinces of Canada and seven major industries at the 2-digit NAICS level over 17 years of annual data from 1997 to 2013.²² The data sources and variable descriptions are provided in Table 1 and the summary statistics are presented in Table 2.

The dependent variable used in the regressions is the logarithm of the capital stock. The year- t capital stock is given by the net capital stock at the end of the preceding year, using geometric depreciation. Of the possible $10 \times 7 \times 17$ province-industry-year observations of capital stocks, there are 108 missing data points, all in the communications or utilities sectors and almost entirely in the Atlantic provinces, and some observations are used up in constructing variables with first differences and lags. There are 15 asset classes of machinery and equipment and 3 asset classes of non-residential construction used in the construction of the METR values. Aggregation of the METRs uses capital weights developed by the federal Department of Finance, which is incorporated into the model of Chen and Mintz. The provincial sales tax component of the METR uses estimates of the share of retail sales tax borne by capital inputs in each industry-province pair, based on revenue statistics classified by industry and type of asset. The economic depreciation rates are asset-specific and estimated by Statistics Canada. The federal and provincial investment tax credits are based on information from *KPMG Tax Facts* booklets and various issues of the Canadian Tax Foundation's publications of *Finances of the Nation*. These and other data used in the construction of the METRs are from the work of Duanjie Chen and Jack Mintz, which are embodied in their annual *Global Tax Competi-*

²² The Mintz-Chen METR calculations are available for manufacturing, construction, communication, transportation, utilities, wholesale and retail trade, other services, and forestry. We excluded the last two industries because other services is a diverse mix, while forestry at the two-digit industry classification level that we use for capital stock data includes agriculture and fishing. The seven major industries used in our sample account for about 70 percent of annual capital investment in Canada (excluding the public sector and non-profits).

tiveness Ranking (see, e.g., Chen and Mintz, 2013). Property taxes and tariffs on machinery and equipment are excluded in the METR calculations.

Cross-sectional variations in the METR capture features of provincial business tax systems. Aside from differences in statutory corporate tax rates, some provinces give generous tax credits and there are important differences in provincial indirect tax systems (e.g., HST versus a retail sales tax).²³ Changes in federal tax rates generate intertemporal variations in the METR, while the preferential treatment of manufacturing over service industries creates tax differences between industries, which also change over time.²⁴ Figure 1 presents the variation in METR across the seven industries in our sample (averaged across the four largest provinces) and Figure 2 does the same for the four largest provinces (averaged across industries). The figures are displayed separately for NRC and M&E. NRC consists of buildings and engineering. M&E (NRC) represents 28 percent (72 percent) of the total stock of M&E and NRC capital. The METRs in both the Figures 2 and 3 steadily decline over time until 2006, then sharply after 2006. It is also evident from Figure 1 that the manufacturing industry received preferential tax treatment, particularly for M&E capital investments. The reduction in the corporate tax rate from 2001–2004 is reflected in the decline in the METR for the service industries. In contrast, since the reduction did not apply to manufacturing, which already benefited from a special lower rate, the METR for manufacturing does not decline during the early 2000s. The most significant changes in the METR occur in 2006–07, following the introduction of accelerated depreciation for asset classes used in manufacturing and processing activities. In Figure 2 the reduction in METR was most striking in Quebec for M&E. Negative values for the METR occur in some years, especially with M&E in the Atlantic provinces, due to the Atlantic Investment Tax Credit.

In computing the user cost, the real interest rate is represented by the yield on the federal government's Real Return Bonds. Industrial price indexes for capital inputs are available from Statistics Canada for each province (by major city, in the case of NRC). An alternative input price series for M&E that is based on imported capital goods, which varies by industry but not by province, is used as a robustness check. Data on industrial output prices are unavailable. Hence, we used the industry level CPI as the output price variable. Industry-specific provincial real GDP is used to represent the accelerator component of desired capital.

B. Unit Roots and Cointegration

Table 3 provides p-values for the results of three common tests for unit roots in each of the variables: the tests of Harris-Tzavalis (1999), Im-Pesaran-Shin (2003), and Hadri (2000), are

²³ Provinces that levy a retail sales tax impose an extra burden on businesses by charging the tax on some capital inputs, but in the provinces with a Harmonized Sales Tax (HST), the incidence does not occur, since the tax base is value added rather than sales. Bird and Smart (2009) argue that this tax policy issue is quantitatively important for understanding inter-provincial investment differences.

²⁴ The industries in our sample typically classified as “service-producing” industries are utilities, communication, transportation, wholesale and retail trade, but the CIT rate for the construction industry is the same as for services.

given in rows 1–3, respectively. The main differences across these tests are the way they treat the aggregation of the test results. Based on this aggregation principle, each test forms a different hypothesis. For instance, the first one runs the test separately for each panel and examines if there exists a unit root in at least some of the panels. The null in the second test is that all panels contain unit roots; while the null for the last test is that all panels are stationary. The first test result indicates that we cannot reject the hypothesis of non-stationarity (in at least some of the panels) of the capital stocks and the user cost for both M&E and NRC, and for GDP, with all variables in logs. The second test fails to reject the hypothesis that all panels contain unit roots for the capital stocks and the user cost of M&E, while rejecting it for the user cost of NRC and for GDP. Finally, the third test rejects the hypothesis that the all panels are stationary in the case of each variable. Overall, the tests suggest the existence of unit roots in the variables.

Table 4 shows results for the Westerlund (2007) panel cointegration test. In the first pair of rows in the table, the G_τ and G_α are the group test statistics for the null hypothesis, that the panel as a whole is not cointegrated, against the alternative that it is. The second pair of rows give the P_τ and P_α panel test statistics, where the null hypothesis is that no panels are cointegrated, against the alternative that at least one of the panels are cointegrated.²⁵ The robust p-values (bootstrapped ten thousand times) are displayed in the table. The results are mixed at conventional levels of statistical significance. For M&E, both group and panel tests provide evidence for the existence of panel cointegration despite the fact that G_α and P_α are only marginally statistically significant at about the 12 percent level. The results are mostly insignificant for NRC, except for the P_τ test that suggests the existence of cointegration in some of the panels. Overall, the tests provide evidence that there is a long-run equilibrium relationship between capital, the user cost of capital, and GDP in the case of M&E, while the evidence is weaker for NRC. Given the evidence of non-stationarity and cointegration between the variables, we estimate an error correction model to impose the restriction of cointegration, as in Dwenger (2014).

IV. EMPIRICAL ESTIMATION

The ECM specification given by (11) contains a lagged dependent variable (implicit in $\Delta k_{i,j,t}$). The correlation between the lagged capital stock and industry-province fixed effects makes OLS estimates biased and inconsistent. To overcome this problem of dynamic panel bias (Nickell, 1981), the model is estimated using the two-step Arellano-Bond System-GMM (Arellano and Bover, 1995, and Blundell and Bond, 1998). System-GMM is preferred to the traditional GMM estimator (Arellano and Bond, 1991), due to the poor finite sample properties of the latter when the dependent variable is a highly persistent series, as in the case of the capital stock. The system-GMM approach removes fixed effects by transforming the variables

²⁵ The α and τ test statistics differ in the details of how the statistic is computed. In the case of α , the computation is done based on the cointegration parameter (α), while in the case of τ , it is based on the t-values of the α coefficient estimates. See Westerlund (2007).

into first differences and then builds instruments to deal with the endogeneity problems.²⁶ Lagged levels of the endogenous variables are used as instruments for the transformed equation, while differences in these variables are used as instruments for the level equation. The first lag of instruments in each specification starts with the last lag specified in the model. We estimate the ECM with up to three lags of the first differences in UCC and GDP. Thus, for instance, if the equation (11) is specified with one lag for the first difference in GDP, then the variables $y_{i,j,t}$ and $\Delta y_{i,j,t-1}$ are instrumented with lags 2-7 of these variables. The instrument matrix is collapsed and the minimal number of instruments is employed, as neither our cross-section nor the time length is large enough to accommodate a large number of instruments, and the Windmejer (2005) robustness correction is applied.²⁷ Time dummies are included to control for year effects. We calculate the Hansen (1982) J-test of overidentifying restrictions to provide evidence of the instruments' validity. This tests the independence of the instruments from the error term. The AR(2) statistic measures second-order serial correlation. Rejection of second-order serial correlation is necessary for the second lags of the endogenous variables to be appropriate instruments for their current values. We also present evidence on the validity of the additional system-GMM instruments from the difference-in-Hansen test.

A. Main Results

Table 5 presents the results of the Bewley-transformed ECM for M&E. The UCE is given by the coefficient of UCC. Columns 1 to 3 yield UCE values ranging from -1.078 to -1.312 , while the GDP elasticities are from 0.568 to 0.621 . The latter figures are much lower than the theoretical value of one from a Cobb-Douglas production function, but they are almost identical to the long-run sales elasticity estimates reported by Dwenger (2014) for the ECM. The coefficients on the dynamic adjustment terms, represented by the variables in first differences, are mostly negative; this is expected theoretically for the differenced GDP terms, but are the wrong sign for the differenced UCC terms, although they are statistically insignificant. The autoregression coefficient on the first-difference of M&E capital is correctly signed in Columns 1 and 2 but not significant. The necessary tests results (i.e. Hansen test on joint validity of instruments and AR(2) test) are satisfactory. The difference-in-Hansen test also provides supporting evidence on the validity of additional system GMM instruments.

As a robustness check, the regressions are repeated but this time with a price index for *imported* M&E used in the calculation of the UCC variable. The alternative price series varies by industry, though not by province. The price for imported M&E mitigates any concern on the possible endogeneity of the price. As can be seen in columns 4 to 6, with the alternative

²⁶ Although with cointegrated data the OLS estimates are superconsistent, we follow Dwenger (2014) in applying IV techniques, based on the conclusions of Hansen and Phillips (1990) that the small sample properties of IV may be superior to those of OLS in cointegrating regressions in the presence of strong endogeneity or low signal-to-noise ratios. We also imitate Dwenger (2014) in adopting a one-step ECM through the Bewley transformation, as a way to avoid biased estimates arising in two-step ECM estimators, when the sample is small (Stock, 1987).

²⁷ Roodman (2009b) provides a comprehensive discussion of system-GMM, while Roodman (2009a) explains the method's shortcomings, especially with respect to too many instruments, and provides remedies.

input price series the UCE remains highly significant and the results are broadly similar to the baseline results. The UCE magnitudes increase to between about 1.6 and 1.8 (in absolute value) while the GDP elasticities decrease to between about 0.3 and 0.5.²⁸

B. METR Semi-Elasticity

The METR semi-elasticity (MSE) has a straight-forward interpretation: a 1 percentage point increase (decrease) in the METR, induced by changes in tax legislation, leads to a decrease (increase) in the capital stock by $100 \times \text{MSE}$ percent. Unlike the UCE, the semi-elasticity value depends on the size of the METR, as well as the real interest rate and the depreciation rate. Table 6 gives the MSE, calculated using a UCE of -1.31 (from column 2 of Table 5) and METR values for M&E of 27.42 percent (column 2) and 10.95 percent (column 3), which correspond to the METRs at the sample mean and the most recent year, respectively.²⁹ The resulting MSEs are -0.32 and -0.22 .

The percentage change in the capital stock is obtained from the elasticities, as follows:

$$\text{long-run change: } \Delta K/K \approx \text{MSE} \times \Delta \text{METR}$$

For example, a 5 percentage point decrease in the marginal effective tax rate (say, from 15 percent to 10 percent via a combination of federal and provincial reductions in the statutory tax rates) would lead to a predicted long-run rise in the M&E capital stock by about 1.1 percent ($100 \times (-0.05) \times (-0.22)$) at the most current average METR value in Table 6. To give a sense of the effect of statutory tax rate changes on changes in METR values, a hypothetical five percentage point reduction in the federal statutory corporate income tax rate in 2009, from 19 percent to 14 percent, would translate into a 3.9 percentage point reduction in the aggregate METR.

C. DLM Estimates for M&E

An alternative to the error correction model is the distributed lag model in first differences, used by Chirinko et al. (1999) and Dwenger (2014). Differencing can be useful to stationarize first-order integrated time series. However, Dwenger (2014) has argued that the DLM in first differences results in an underestimation of the UCE in the presence of a cointegrating relationship between the capital stock and the user cost. Table 7 shows our DLM results for M&E. Columns 1 to 3 correspond to different numbers of lags of the explanatory variables.

²⁸ Due to generous tax credits for investments in M&E in the Atlantic Provinces, the METRs are “large” negative values in some years in those provinces. As firms can only benefit from such implicit subsidies if they have offsetting profits in other activities, we also checked the effect of resetting the METR to zero whenever it is negative. This change had negligible effects on the results.

²⁹ For this purpose, annual weighted-average METR values are constructed using the province-industry capital weights. In the computation of $dc/d\text{METR}$ in (9), the weighted average depreciation rate for M&E is 22 percent and r^* is 0.0349.

The UCE is given by the sum of the coefficients on the changes in the user cost of capital (in logs). The UCE estimates are between -0.098 and -0.424 . In column 2, the sum of the UCC coefficients is significantly different from zero at 10 percent. The UCE are not statistically significant in columns 1 and 3. The elasticity with respect to GDP in column 2 is 0.380, but it is zero or even negative in the other columns. Taking the results in column 2 as the best fit, the DLM estimates indicate a UCC elasticity for M&E of approximately -0.4 . Columns 4 to 6 are included again as a robustness check, whereby the price of imported M&E is used to construct the UCC variable to mitigate any concerns about the endogeneity of the price of capital. Using this alternative price data does not alter the general findings from the regressions of columns 1 to 3. The Hansen test confirms the validity of the instruments, while the AR(2) test results confirm the non-existence of autocorrelation of order 2 in most cases, except in the case of the specification with a single lag according to a five percent significance level.

The results in Table 7 corroborate the finding of Dwenger (2014), that the magnitude of the UCE from the DLM is considerably smaller than from the ECM.

D. Discussion of Non-Residential Construction

We have focused on the results for machinery and equipment. Comparable estimates for non-residential construction, using both the ECM and DLM approaches, generate UCE values for NRC that are statistically insignificantly different from zero and in some specifications the coefficients have the wrong signs (see Table A1 in the appendix). The general results echo Schaller's (2006) findings on the UCE for NRC in the macro data, as well as the conclusion of ab Iorwerth and Danforth (2004: 14) that, for non-residential construction, "parameter estimates were often insignificant and of the wrong sign and the overall fit of these models was poor." What might explain this puzzling outcome?

ab Iorwerth and Danforth noted that the observed secular and permanent decline in the price of information technology investments can help to identify the UCE for M&E in a cointegration framework and that the absence of a similar decline in the price of NRC investments may help explain why a non-zero UCE for this form of capital has been elusive. Moreover, we observe less interprovincial and inter-industry variations in the METR for NRC than in the METR for M&E (see Figures 1 and 2), with variation in the latter driven by accelerated depreciation for M&E in some of the provinces. Other possible reasons for the poor fit of the NRC models rest with the construction of the METR and hence with the user cost of capital. If a corporation constructs its own building, for example, then there is a time-to-build aspect of the investment, which is not factored into the standard METR calculations that are used in our analysis. Furthermore, the long-lived nature of non-residential construction may make such investments more susceptible to uncertainty about future economic conditions. The METR for irreversible investment under uncertainty differs from the conventional METR (see McKenzie, 1994). An agenda for future research is to modify the METR calculations for NRC to take into account time-to-build and uncertainty. The important differences in the elasticities for M&E versus NRC suggest that disaggregating these forms of capital in the em-

irical analysis may be important for understanding the market's responses to changes in tax policies (Caballero, 1994, Schaller, 2006, and Smith, 2008).

V. CONCLUSIONS

We have estimated the long-run user cost elasticity (UCE) of capital, together with the implied semi-elasticity with respect to the marginal effective tax rate (METR), using an error correction model (ECM). The method exploits a cointegrating relationship between the capital stock, the user cost, and GDP, for which we provide evidence. The empirical analysis uses three sources of variation in tax policies to identify the tax-adjusted user cost elasticities: intertemporal, inter-industry, and inter-provincial. The small open economy situation of Canada diminishes concerns over the potential endogeneity of interest rates and the prices of capital goods, which pose challenges to estimating the UCE in large economies, such as the United States and Germany, which have been the focus of the literature. While previous studies for Canada have used exclusively national data, we use provincial data on seven industries, spanning manufacturing and services, over the period 1997–2013. Our user cost variables are based on the very detailed METR model developed by Duanjie Chen and Jack Mintz.

We find that the estimated elasticities for machinery and equipment are plausible and statistically significant, while the results for non-residential construction are not. However, as M&E accounts for 28 percent of the total of M&E and NRC in Canada, the results for M&E are important for understanding the effects of tax policy on real capital investments. Using a Bewley-transformed ECM, we find a UCE of about -1.3 for M&E. The estimate adds to the very few recent studies of the UCE based on data from a small open economy. The implied semi-elasticity with respect to the METR is about -0.2 when evaluated at the weighted-average METR for M&E of 11 percent (the most recent value in the sample). An alternative estimate based on a distributed lag model in first differences yields a lower UCE for M&E of about -0.4 , consistent with the arguments put forth by Dwenger (2014) on the likely underestimation of the UCE by stationary econometrics.

Applying an elasticity of -1.3 for M&E and zero for NRC, our results suggest a weighted-average UCE estimate of about -0.4 for the total of M&E and NRC, or equivalently, an overall semi-elasticity of -0.06 . If the overall elasticity is applicable to *all* categories of physical capital (not just construction and machinery & equipment, but also land and inventories), then the result suggests that the reduction in the aggregate METR for Canada from 28.0 percent in 2009 to 20.0 percent in 2015 (Chen and Mintz, 2015) may have increased the national capital stock in Canada by 0.5 percent over the long run, holding all other influences on investment constant. The increased investments stemming from the tax cuts likely had positive impacts on productivity and wages. Finally, it is important to observe that efficient allocations of real capital depend not only on the level of the METR, but also on the degree of dispersion of METRs across industries, provinces, and types of capital.

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Figure 1. Average METR by Industry, 1997–2013

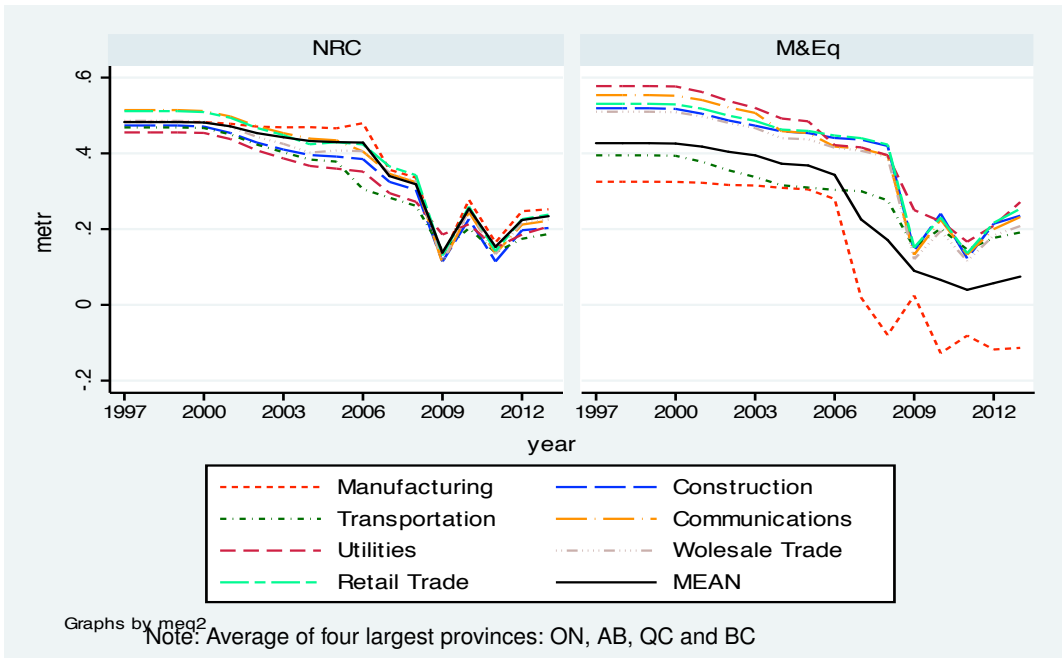


Figure 2. Average METR by largest Canadian Provinces, 1997–2013

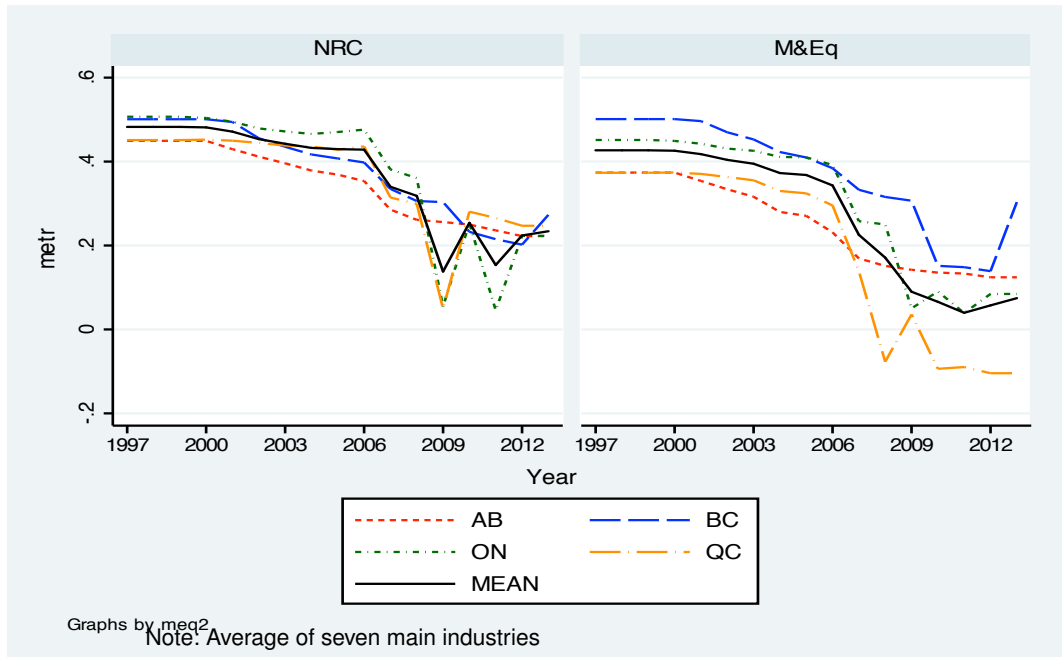


Table 1. Data Description and Sources

Variable Name	Unit	Source
Tax and Capital variables		
Marginal Effective Tax Rates (METR)	percent	School of Public Policy of University of Calgary
Real Capital Stock	2007 CAD	CANSIM 310002
Input Prices		
Capital Input Prices	index (2002)	CANSIM 3840039
Machinery and Equipment Import Price	index (2002)	CANSIM 18100107
Output Price (Components of CPI)		
Utilities (Water, fuel and electricity)	index (2002)	CANSIM 3260021
Transportation (Inter-city Transportation)	index (2002)	CANSIM 3260021
Construction (Shelter)	index (2002)	CANSIM 3260021
Retail (Goods and Service)	index (2002)	CANSIM 3260021
Communication	index (2002)	CANSIM 3260021
Manufacturing	index (2002)	CANSIM 3290056
Wholesale*	index (2002)	CANSIM 810009
Other Variables		
Real GDP	Chained 2007 Dollars	CANSIM 3790030
Real Return on Long-Term Canadian Bonds	percent	CANSIM 1760043

*Wholesale data is available for the period 2002-2009 and the rest of the years were extrapolated from using growth of CPI in the relevant years.

Table 2. Summary Statistics

Variable Name	Obs	Mean	Std Dev.	Min	Max
Building and Engineering (NRC) Capital Stock	1088	6074.7	9708.5	19.7	57683.6
Machinery and Equipment (MEq) Capital Stock	1088	2397.1	4422.9	10.2	32195.8
METR for NRC	1190	0.35	0.13	-0.05	0.56
METR for MEq	1190	0.35	1.08	-4.70	14.39
Relative input/output Price for Building Engineering	1190	1.10	0.14	0.65	1.68
Relative input/output Price for Machinery and Equipment	1190	0.87	0.21	0.40	1.44
Relative imported input/output Price for Machinery and Equipment	1190	0.81	0.18	0.45	1.24
Real Interest rate	1190	2.43	1.19	0.42	4.13
Real GDP	1190	7682	12924	26	97938

Time period is 1997–2013. All the variables, except real interest rate, vary by province and industry. The capital stock is defined as geometric (infinite) end-year net stock and lagged for one period, $K_t = K_{t-1}$.

Table 3. Panel Unit Root Tests

Test	Ho	Capital Stock		UCC		GDP
		M&E	NRC	M&E	NRC	
1 Harris-Tzavalis	Panels contain unit roots	1.00	1.00	1.00	1.00	1.00
2 Im-Pesaran-Shin	All panels contain unit roots	0.46	0.87	0.13	0.02	0.00
3 Hadri LM test	All panels are stationary	0.00	0.00	0.00	0.00	0.00

The table shows p-values. In all the tests, the mean of variables are subtracted and a time trend considered. All of the variables are in logs.

Table 4. Panel Cointegration Tests

Statistic	Capital Stocks, UCC and GDP					
	M&E			NRC		
	value	z-value	p-value	value	z-value	p-value
<i>Groups</i>						
G_τ	-1.79	-3.10	0.01	-0.87	3.89	0.50
G_α	-1.78	5.91	0.12	-1.31	6.61	0.34
<i>Panels</i>						
P_τ	-7.37	0.09	0.00	-7.79	-0.22	0.06
P_α	-1.09	2.30	0.11	-1.13	2.23	0.14

In all of the tests, the null hypothesis is “no co-integration exists.” Robust (bootstrapped ten thousands times) p-values are reported. One lead and one lag is included in all of the tests. The results are robust to adding a constant term and a time trend. All of the variables are in logs.

Table 5. Results from Error Correction Model, Estimated by System GMM (Arellano-Bond), for Machinery and Equipment Capital Stock

Variables	Baseline Results			Robustness Check		
	1	2	3	4	5	6
$\Delta\log(\text{Capital Stock for MEq})_t$	-0.332 [0.711]	-2.419 [2.071]	0.404 [1.225]	-0.501 [0.583]	-2.667 [2.110]	0.301 [1.140]
Log of UCC_t	-1.078* [0.592]	-1.312*** [0.345]	-1.206*** [0.416]	-1.686** [0.828]	-1.561*** [0.436]	-1.756*** [0.532]
Log of GDP_t	0.589* [0.300]	0.621*** [0.189]	0.568** [0.245]	0.308 [0.338]	0.540** [0.212]	0.482* [0.285]
$\Delta\log(\text{UCC for MEq})_t$	0.245 [0.680]	0.037 [0.749]	0.109 [0.973]	0.566 [0.856]	0.144 [0.684]	0.512 [0.800]
$\Delta\log(\text{UCC for MEq})_{t-1}$	-0.472 [0.653]	-0.946 [0.988]	-1.382 [1.364]	-0.404 [0.674]	-0.848 [0.835]	-0.778 [1.041]
$\Delta\log(\text{UCC for MEq})_{t-2}$		-0.957 [0.806]	-1.763 [1.414]		-0.764 [0.709]	-1.143 [0.990]
$\Delta\log(\text{UCC for MEq})_{t-3}$			-1.442 [1.135]			-1.026 [0.802]
$\Delta\log(\text{GDP})_t$	-0.526 [1.513]	-3.076 [2.360]	-0.391 [1.985]	-0.093 [1.301]	-2.926 [2.382]	-1.602 [1.685]
$\Delta\log(\text{GDP})_{t-1}$	-0.193 [0.219]	-4.713 [2.982]	-1.474 [2.394]	-0.164 [0.215]	-5.209 [3.405]	-0.589 [2.186]
$\Delta\log(\text{GDP})_{t-2}$		-0.410 [0.360]	1.401 [1.879]		-0.259 [0.451]	1.574 [1.785]
$\Delta\log(\text{GDP})_{t-3}$			-0.584 [0.409]			-0.396 [0.324]
Observations	960	896	832	960	896	832
Number of Cross-Sections	64	64	64	64	64	64
Number of Instruments	40	39	38	40	39	38
AR(1) P-Value	0.787	0.357	0.324	0.953	0.245	0.670
AR(2) P-Value	0.844	0.170	0.339	0.745	0.175	0.308
Hansen Test (Joint Validity) P-Value	0.819	0.728	0.414	0.973	0.868	0.791
Difference-in-Hansen Test of Exogeneity of Instrument Subsets (P-Value)						
Hansen Test Excluding Group	0.952	0.916	0.284	0.983	0.996	0.771
Difference (null H = exogenous)	0.241	0.301	0.486	0.575	0.316	0.63

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Clustered (by Province X Industry) standard errors are in brackets. The dependent variable is the logarithm of the capital stock. A full set of time dummies is included, and Province X Industry fixed effects are removed by the estimation in first-differences. Capital stock and GDP variables are treated as endogenous. The instruments for the differenced equation are the lagged levels, and for the level equation are the lagged first-differences of the endogenous variables. Instruments are constructed with the first available seven lags following the last lag included in the model. For instance, in column (1), GDP variables are instrumented with lags 2–7. “Baseline Results” display the estimates for UCC computed with the main price index for machinery and equipment in Canada, while the “Robustness Check” does the same but now with a price index of imported machinery and equipment.

Table 6. METR Semi-Elasticities of the M&E Capital Stock

UCE = -1.312	Average METR (27.42%)	Recent METR (10.95%)
Semi-elasticity (MSE)	-0.324	-0.223

Table 7. Results from Distributed Lag Model, Estimated by System GMM (Arellano-Bond), for Machinery and Equipment Capital Stock

Variables	Baseline Results			Robustness Check		
	1	2	3	4	5	6
$\Delta\log(\text{UCC for MEq})_t$	-0.0209 [0.0654]	-0.0771 [0.0574]	-0.0355 [0.0832]	-0.0387 [0.0675]	-0.109 [0.0726]	-0.0909 [0.0922]
$\Delta\log(\text{UCC for MEq})_{t-1}$	-0.0770 [0.0864]	-0.224* [0.121]	-0.135 [0.126]	-0.112 [0.0791]	-0.284* [0.146]	-0.245 [0.153]
$\Delta\log(\text{UCC for MEq})_{t-2}$		-0.122 [0.117]	-0.0138 [0.129]		-0.190 [0.157]	-0.126 [0.172]
$\Delta\log(\text{UCC for MEq})_{t-3}$			0.104 [0.108]			-0.00252 [0.116]
Sum of $\Delta\log(\text{UCC})$	-0.0980	-0.424*	-0.0799	-0.151	-0.583*	-0.464
F-Test (Joint Significance) P-Value	0.496	0.0912	0.817	0.270	0.0782	0.287
$\Delta\log(\text{GDP})_t$	-0.286 [0.586]	0.745 [0.662]	-0.278 [0.888]	-0.269 [0.564]	0.848 [0.731]	-0.325 [0.869]
$\Delta\log(\text{GDP})_{t-1}$	0.0848 [0.0911]	-0.484 [0.529]	0.677 [0.462]	0.0829 [0.0901]	-0.454 [0.535]	0.699 [0.464]
$\Delta\log(\text{GDP})_{t-2}$		0.119 [0.0988]	-0.652 [0.418]		0.120 [0.0976]	-0.685 [0.434]
$\Delta\log(\text{GDP})_{t-3}$			0.231* [0.127]			0.235* [0.123]
Sum of $\Delta\log(\text{GDP})$	-0.201	0.38	-0.022	-0.186	0.514	-0.076
F-Test (Joint Significance) P-Value	0.709	0.591	0.979	0.719	0.492	0.922
Observations	960	896	832	960	896	832
Number of Cross-Sections	64	64	64	64	64	64
Number of Instruments	26	27	28	26	27	28
AR(1) P-Value	0.00924	0.0280	0.0218	0.00760	0.0386	0.0190
AR(2) P-Value	0.0364	0.578	0.348	0.0363	0.618	0.300
Hansen Test (Joint Validity) P-Value	0.104	0.523	0.149	0.106	0.488	0.156

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Clustered (by Province X Industry) standard errors are in brackets. The dependent variable is the logarithm of the capital stock. A full set of time dummies is included, and Province X Industry fixed effects are removed by the estimation in first-differences. Capital stock and GDP variables are treated as endogenous. The instruments for the differenced equation are the lagged levels, and for the level equation are the lagged first-differences of the endogenous variables. Instruments are constructed with the first available seven lags following the last lag included in the model. For instance, in column (1), GDP variables are instrumented with lags 2–7. “Baseline Results” display the estimates for UCC computed with the main price index for machinery and equipment in Canada, while the “Robustness Check” does the same but now with a price index of imported machinery and equipment.

APPENDIX A. DISTRIBUTED LAG MODEL IN FIRST DIFFERENCES (DLM)

The general distributed lag model in first differences is written as

$$\Delta k_{i,j,t} = \rho \Delta k_{i,j,t-1} + \sum_{h=0}^{H_y} \beta_h \Delta y_{i,j,t-h} - \sum_{h=0}^{H_c} \theta_h \Delta c_{i,j,t-h} + \xi_{i,j,t} \quad (1)$$

where $\Delta x_{i,j,t-h} \equiv \ln X_{i,j,t-h} - \ln X_{i,j,t-h-1}$ expresses the variables in terms of growth rates and $\xi_{i,j,t}$ is an error term. The estimating equation in Chirinko et al. (1999) is obtained by restricting the autoregressive parameter, ρ , to be zero in (1).³⁰ In that case, the permanent change in the capital stock (in percentage), resulting from an increase in the user cost (in percentage), say, Δc sustained over H_c periods, is equal to the sum of the θ_h coefficients,

$$UCE = - \sum_{h=0}^{H_c} \theta_h \quad (2)$$

³⁰ Chirinko et al. (1999) estimate the equation (1) with $\rho = 0$ (after a further substitution that approximates the left-hand side of the equation with an investment-to-capital ratio). In their model, $\rho = 0$ is implied by an assumption that capital adjusts according to the weighted geometric mean of relative changes in the desired capital stock; i.e.,

$$K_t = K_{t-1} \prod_{h=0}^H (K_{t-h}^* / K_{t-h-1}^*)^{\mu_h} .$$

Table A1. Main Results from Both Models, Estimated by System GMM (Arellano-Bond), for Non-Residential Construction Capital Stock

Variables	Error Correction Model			Distributed Lag Model		
	1	2	3	4	5	6
$\Delta\log(\text{Capital Stock for NRC})_t$	0.408 [2.261]	0.571 [3.216]	0.336 [6.008]			
Log of UCC_t	1.555 [2.108]	1.272 [1.903]	0.084 [2.702]			
Log of GDP_t	0.659* [0.374]	0.469* [0.260]	0.913*** [0.241]			
$\Delta\log(\text{UCC for NRC})_t$	-1.725 [1.648]	-1.733 [1.780]	-0.857 [2.712]	-0.0202 [0.0258]	-0.00312 [0.0495]	-0.0126 [0.0383]
$\Delta\log(\text{UCC for NRC})_{t-1}$	-1.387 [0.986]	-1.795 [1.885]	-1.387 [2.623]	-0.0382* [0.0227]	-0.0232 [0.0582]	-0.0149 [0.0493]
$\Delta\log(\text{UCC for NRC})_{t-2}$		-1.240 [1.355]	-1.426 [2.386]		-0.00786 [0.0567]	-0.0362 [0.0519]
$\Delta\log(\text{UCC for NRC})_{t-3}$			-1.188 [1.106]			-0.0117 [0.0447]
Sum of $\Delta\log(\text{UCC})$				-0.0584	-0.0342	-0.0755
Prob >F				0.206	0.823	0.586
$\Delta\log(\text{GDP})_t$	-4.427 [7.434]	-4.550 [5.739]	-7.198 [9.668]	0.0538 [0.281]	-0.218 [0.502]	0.271 [0.344]
$\Delta\log(\text{GDP})_{t-1}$	-0.642 [0.783]	-4.961 [5.101]	-6.753* [3.636]	-0.0110 [0.0260]	-0.120 [0.253]	0.0948 [0.296]
$\Delta\log(\text{GDP})_{t-2}$		-0.390 [0.631]	-4.040 [4.656]		-0.0107 [0.0613]	0.422* [0.246]
$\Delta\log(\text{GDP})_{t-3}$			-1.093 [0.711]			0.0131 [0.0506]
Sum of $\Delta\log(\text{GDP})$				0.0428	-0.349	0.801
Prob >F				0.874	0.609	0.191
Observations	615	574	533	960	896	832
Number of new_id	41	41	41	64	64	64
Num. of Instruments	40	39	38	26	27	28
AR(1) P-Value	0.454	0.502	0.329	0.00678	0.144	0.0786
AR(2) P-Value	0.738	0.246	0.953	0.813	0.951	0.389
Hansen Test (Joint Validity) P-Value	0.980	0.174	0.119	0.190	0.0579	0.0568

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Clustered (by Province X Industry) standard errors are in brackets. The dependent variable is the logarithm of the capital stock. A full set of time dummies is included, and Province X Industry fixed effects are removed by the estimation in first-differences. Capital stock and GDP variables are treated as endogenous. The instruments for the differenced equation are the lagged levels, and for the level equation are the lagged first-differences of the endogenous variables. Instruments are constructed with the first available seven lags following the last lag included in the model. For instance, in column (1), GDP variables are instrumented with lags 2–7.