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Could higher taxes increase the long-run demand for capital? Theory and evidence for Chile

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Abstract

On theoretical grounds alone, there is no a priori reason why higher taxes should reduce the desired capital stock, since a tax increase reduces marginal returns but also increases depreciation and interest payment allowances. Using a panel of Chilean corporations, this paper estimates a long-run demand for capital valid for a general adjustment-cost structure. Changes in the corporate tax rate are found to have no effect on the long-run demand for capital. Furthermore, when making investment decisions, firms ignore the marginal rates paid by their stockholders, suggesting the presence of a corporate veil.

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1. Introduction

Is a tax increase always detrimental for capital formation? Could such an increase lead to a higher capital stock? More generally, what determines the relation between the long-run demand for capital and taxes? In this paper we combine an extension of Hall and Jorgenson's (1967) neoclassical model with the cointegration argument in Bertola and Caballero (1990) to provide both theoretical and empirical answers to these questions without taking a stance on the nature of capital adjustment costs (convex versus nonconvex). We estimate the model with a panel of 83 large publicly held Chilean firms

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between 1985 and 1995. We find that in some years (10 out of 11) higher business taxes increase the aggregate long-run demand for capital, while in other years (1 out of 11) it reduces it; in all years the influence is negligible. We also find evidence of a corporate veil, that is, when making their investment decisions, firms do not take into account the personal income taxes paid by its shareholders.

Is it surprising that higher taxes may not affect or even increase the desired capital stock? It is often stressed in policy discussions that higher taxes reduce returns and discourage investment. But this argument ignores that capital investments also reduce the firm's tax bill: first, depreciation allowances reduce taxable profits; second, capital investments are partly financed by debt and interest payments are tax-deductible. As King (1977, p. 234) showed, when the sum of these discounts is large enough, a higher corporate tax rate reduces the cost of capital. It follows that, on theoretical grounds, there is no a priori reason suggesting that higher taxes necessarily reduce the capital stock.

In this paper we show that for a sample of relatively large publicly held Chilean firms, depreciation allowances and interest deductions are, on average, large enough to make the business tax close to nondistortionary—the tax rate affects the user cost of capital very little. Thus, the desired capital stock is quite insensitive to changes in the business tax rate. For example, an increase of the business tax from 0 to 20% leads, depending on the year, to a change in the desired capital stock between -0.12% (1990) and 1.25% (1995).¹

It is worth stressing that this result does not obtain because the desired capital stock is insensitive to changes in the user cost of capital. We estimate an average elasticity of substitution between capital and labor across sectors of -0.62 , which is not far from the neoclassical benchmark value of -1.0 . We also show that changes in tax rates explain a minor fraction of fluctuations in the user cost of capital; this contrasts with variations in the price of capital and in the interest rate, which explain more than 90% of the variation in the user cost of capital between 1985 and 1995. In other words, taxes are nearly irrelevant because depreciation allowances and interest deductions are similar to the acquisition cost of assets and, consequently, do not affect the relevant relative price—the user cost of capital.

The preceding conclusion is valid when firms ignore the personal taxes paid by their stockholders (that is, there is a 'corporate veil'). Our theoretical contribution is to extend the work of Hall and Jorgenson (1967) and King (1974) to tax structures like those in Chile, where corporate and personal income taxes are integrated.² We show that, theoretically, the personal tax rate affects the user cost of capital when expected to change from one period to another. Since personal tax rates changed in Chile in three of the 11 years covered by the sample, and, moreover, we have a panel of 83 firms, we are able to

¹ Jorgenson and Landau (1993, Table 1-1) find negative marginal effective corporate tax rates in 1990—which in our framework correspond to having the demand for capital increase after an increase in the business tax rate—for two (France and Italy) of the nine countries they consider (the remaining countries are Australia, Canada, Germany, Japan, Sweden, United Kingdom and United States). Auerbach (1983) calculates similar tax rates for equipment and structures in the United States, for the 1953–1982 period, and finds a negative effective rate only for the equipment tax rate in 1981. To our knowledge, this paper is the first instance where effective tax rates on capital are found to be negative in a developing country.

² See Engel et al. (1999) for a primer on the Chilean Tax System.

test whether personal taxes affect the demand for capital.³ We find evidence suggesting the presence of a corporate veil.

The theoretical and empirical results we present strongly suggest that taxes are irrelevant for firms' capital stock. To temper this conclusion, we discuss its scope and further explain what we do and do not do in this paper.

First, we do not estimate the demand for investment (the flow), but the long-run demand for capital (the stock). Second, we ignore the possibility that higher business taxes may reduce the cash-flow of financially constrained firms, an assumption consistent with considering a sample of large corporations with expedite access to the Chilean financial market in the empirical part.⁴

Third, this is a partial equilibrium analysis. In both the theoretical derivation and estimation, we suppose that the interest rate is exogenous and does not depend on taxes.⁵ We also ignore the effect of taxes on financing decisions, since we assume a constant long-run debt–capital ratio for each firm, the determinants of which (presumably agency problems) we do not model.⁶ It follows that, within our framework, firms with restricted access to the capital market will have a lower debt–capital ratio. Thus, it is likely that for firms smaller than those in our sample, higher taxes not only reduce firms' cash flow but directly increase their user cost of capital, thereby reducing their desired capital stock.

The rest of the paper is organized as follows. The theoretical model is developed in Section 2. Section 3 describes the empirical model and the data. Results are presented in Section 4, and Section 5 concludes.

2. Theory

2.1. The model

Following Jorgenson (1963) and Hall and Jorgenson (1967), we model a neoclassical firm that produces the numerary good Y using capital (K) and labor (L) with a constant returns to scale production function $Y(K,L)$.⁷ Employment can be adjusted instantaneously. The capital stock is a state variable that evolves at instant t according to

$$\dot{K} = I_t - \rho K_t, \tag{1}$$

where I_t is gross investment, \dot{K}_t the instantaneous variation of the capital stock, and ρ the (constant) rate of depreciation. We also assume that the firm reinvests all

³ Heterogeneity across firms in the composition of their capital stock allows us to calculate firm specific user costs, thereby providing sufficient variability to make our estimation exercise meaningful.

⁴ In a recent paper, Hsieh and Parker (2002) argue that a substantial part of the Chilean investment boom of the late eighties was financed with the tax cut on retained profits enacted in 1984. Medium and small sized manufacturing firms with constrained access to financial markets play a central role in their argument.

⁵ See Lucas (1990) for a general equilibrium model that examines the effect of taxes on consumption and capital accumulation.

⁶ See King (1974). Budnevich and Jara (1997) examine corporate saving decisions in Chile between 1984 and 1992.

⁷ To ensure the problem is well defined, we assume the firm faces a downward sloping, constant elasticity demand curve.

retained profits in physical capital, so that the debt–capital ratio, b , is constant and exogenous.

At each moment in time accounting pretax profits are equal to

$$Y(K_t, L_t) - wL_t - rD_t - \Delta_t,$$

where w is the wage, r is the interest rate at which the firm borrows (which is supposed to be constant and exogenous), $D_t \equiv \int_0^t b p_s I_s ds$ is the debt the firm has acquired from instant 0 until instant t to finance gross investment, p_t is the relative price of capital goods at t and $\Delta_t \equiv \int_0^t \delta_{t-s} p_s I_s ds$ is the sum of the depreciations that the tax law allows at instant t for capital goods acquired by the firm up to that instant. We suppose that a capital good acquired at time t can depreciate at $t + s$ a fraction δ_s of its initial acquisition value, $p_t I_t$, and that $\int_0^\infty \delta_s ds = 1$. For future reference, it is useful to define an expression of the present value of the discounts for depreciation when \$1 are invested today. This corresponds to

$$z \equiv \int_0^\infty e^{-rs} \delta_s ds,$$

an amount which, as a result of the preceding assumptions, is less than 1.

The cash flow generated by the firm at t , before investing, is equal to $(1 - \tau)[Y(K_t, L_t) - wL_t - rD_t] + \tau \Delta_t$, where τ is the corporate tax rate paid on profits retained by the firm; henceforth we will call τ the ‘corporate tax’. Since profits that are retained are reinvested in the firm, dividends paid at t are equal to

$$\text{div}_t \equiv (1 - \tau)[Y(K_t, L_t) - wL_t - rD_t] + \tau \Delta_t - (1 - b)p_t I_t.$$

2.2. The firm maximizes the present value of its dividend payments

The first case we examine is a firm that maximizes the present value of the dividends it pays, ignoring that stockholders pay personal taxes.⁸ The firm chooses K_0 and the trajectories of L and I to maximize

$$\int_0^\infty e^{-rt} \text{div}_t dt,$$

or

$$\int_0^\infty e^{-rt} \{ (1 - \tau)[Y(K_t, L_t) - wL_t - rD_t] + \tau \Delta_t - (1 - b)p_t I_t \} dt, \tag{2}$$

subject to Eq. (1).

⁸ The derivation that follows is standard in this literature; we include it to facilitate the comprehension of the case where personal taxes are added.

Solving the firm’s optimization problem (see Appendix A) yields:

$$Y_K = \frac{[1 - \tau(b + z)]}{1 - \tau} [(r + \rho)p_t - \dot{p}_t] \equiv v_t^V. \tag{3}$$

In expression (3), Y_K is the instantaneous marginal income from adding one unit to the capital stock. The right-hand side is the so-called user cost of capital, which we shall denote by v_t^V .⁹

When $\tau = 0$ and $p_t = 1$, the user cost of each dollar invested is equal to the sum of its opportunity cost, r , and the loss from depreciation of that unit of capital, ρ . Capital gains resulting from changes in its price must be deducted. The corporate tax affects the user cost of capital for two reasons. First, part of the interest for the debt that generates an additional dollar of investment can be discounted as cost, which saves the firm τb in present value for each dollar invested;¹⁰ moreover, a fraction z of the value that was invested can be discounted as depreciation, generating a tax saving equivalent to τz . These discounts reduce the user cost. On the other hand, the corporate tax reduces the additional income per extra unit of capital to $Y_K(1 - \tau)$; this effect appears in the denominator of v_t^V , and increases the user cost. Since these two effects go in opposite directions, the conclusion is that the overall effect is ambiguous. For example, if the corporate tax is increased, it will not necessarily reduce the desired capital stock. There are five consequences that should be pointed out:

1. When the firm is completely financed with internal funds ($b = 0$) and the present value of the discounts for depreciation permitted by law is equal to the amount invested ($z = 1$), the level of the tax rate on firms is irrelevant, since in this case $Y_K = (r + \rho)p - \dot{p}$. In other words, both effects cancel out exactly.
2. The same applies when the firm is allowed to discount as a cost all disbursements for investment at the time they take place (this is equivalent to $z = 1$), and it is not allowed to discount any of the interest it pays on the debt (which is the equivalent to making $b = 0$ for tax purposes). This is the so-called cash flow tax, which makes corporate taxes nondistortionary (see King, 1977, p. 238).
3. When $b + z > 1$, the user cost is lower the higher the tax rate. This occurs because in this case the firm can discount as cost more than \$1 for each dollar invested. Therefore, the higher the tax rate, the higher the value of the discounts and, consequently, the desired capital stock. (Note that in this case the demand for capital is not infinite because diminishing returns set in.)
4. The foregoing implies that one cannot say a fortiori that higher corporate tax rates reduce the desired capital stock.
5. Last, all derivations assumed that there was no inflation. This is the right model for Chile because the tax system is fully indexed every month.

⁹ Superscript V refers to the fact this is user cost with corporate veil.

¹⁰ Note that this means the firm would like to choose $b = 1$. However, in practice, firms cannot finance themselves exclusively with debt, presumably because of agency problems that are not modelled here.

2.3. Personal taxes

The preceding subsection assumed that firms ignore the personal taxes paid by their stockholders when making investment decisions (the so-called corporate veil). Clearly, the stockholders of a firm are interested in maximizing the present value of the dividends they receive after paying all taxes which, in Chile, include corporate and personal taxes.¹¹ In this section we solve the model, assuming that the firm chooses its investment path to maximize the present value of dividends net of all taxes. To simplify the calculations, we suppose the firm has just one owner whose only source of income are dividends paid by the firm.

To define the objective function of the owner of the firm, it is necessary to consider that in the Chilean tax system the corporate tax paid by the firm is a credit against the personal income tax. This credit operates as follows: if τ is the tax rate on profits and τ^m is the marginal tax rate on personal income, then a dividend of div_t will pay taxes of:¹²

$$\frac{\tau^m - \tau}{1 - \tau} div_t. \tag{4}$$

The objective function of the owner then becomes:

$$\int_0^\infty e^{-rt} \left[1 - \frac{\tau^m - \tau}{1 - \tau} \right] div_t dt = \frac{1}{(1 - \tau)} \int_0^\infty e^{-rt} (1 - \tau^m) div_t dt. \tag{5}$$

In a general formulation, the average personal tax rate that an individual pays depends on his income level, credits received, and the progressivity of the tax rate. Let $\tau_t^P: \mathbb{R}^+ \rightarrow [0,1]$ denote the progressive marginal tax schedule at t and $\bar{\tau}_t^P: \mathbb{R}^+ \rightarrow [0,1]$ the corresponding average tax rate schedule. We assume both functions are differentiable with respect to income and time.

Thus, the firm selects the L and I trajectories to maximize

$$\int_0^\infty e^{-rt} (1 - \bar{\tau}_t^P) div_t dt, \tag{6}$$

subject to Eq. (1).¹³ (Henceforth we will write $\bar{\tau}_t^P$ for $\bar{\tau}_t^P(div_t)$.) In this case, it is not possible to directly transform Eq. (6) into an expression analogous to Eq. (19), which would permit the application of the Hamiltonian method. The reason is that the average rates paid by the owner of the firm may depend on the moment when dividends are paid. In that case, the timing of tax savings due to depreciation and interest payments matters.

¹¹ Unlike in the United States, corporate and personal taxes are fully integrated and corporate taxes are credited against personal taxes.

¹² Before 1990, the rate was not $(\tau^m - \tau)/(1 - \tau)$, but $\tau^m - (\tau_{1a} + \tau_a)$, where τ_{1a} and τ_a denote the so-called First Category and Additional taxes, which determined the tax on profits. The following derivation is valid for both expressions of the personal marginal tax rate.

¹³ By omitting the factor $1/(1 - \tau)$ on the right side of Eq. (5), we are assuming that changes in τ are not anticipated by the owner of the firm.

To simplify, we will assume that the tax savings generated by depreciation and interest on the debt increase the firm’s cash flow at the time the investment takes place.¹⁴ Under this assumption:

$$\text{div}_t = (1 - \tau)[Y_t - wL_t] - [1 - \tau(b + z)]p_tI_t. \tag{7}$$

In principle, personal taxes add two new effects. First, the optimal trajectory of dividend payments will depend on how the relevant marginal rate for the owner of the firm is expected to vary. For example, if a fall in rates is expected in the future, it will become more profitable to postpone dividends and reinvest more today. The second effect is that, assuming that the firm can borrow against future tax savings to finance current investment, the owner can choose when it is most advantageous to pay dividends. The assumption that leads to Eq. (7) captures the first effect but ignores the second, by forcing the firm to include the saving on future taxes in the cash flow of the period when the investment is made. In exchange for this simplification, one obtains an expression that can be estimated econometrically.¹⁵

Under the assumption mentioned, the associated Hamiltonian is

$$\mathcal{H} = e^{-rt}(1 - \bar{\tau}_t^P)\text{div}_t + \lambda_t(I_t - \rho K_t).$$

where div_t is now given by Eq. (7). The first-order conditions are

$$\frac{\partial \mathcal{H}}{\partial L_t} \equiv e^{-rt}(1 - \tau_t^P)(1 - \tau)(Y_L - w) = 0; \tag{8}$$

$$\frac{\partial \mathcal{H}}{\partial I_t} \equiv -e^{-rt}(1 - \tau_t^P)[1 - \tau(b + z)]p_t + \lambda_t = 0; \tag{9}$$

$$\frac{\partial \mathcal{H}}{\partial K_t} + \dot{\lambda}_t \equiv e^{-rt}(1 - \tau_t^P)(1 - \tau)Y_K - \rho\lambda_t + \dot{\lambda}_t = 0, \tag{10}$$

where we have used the fact that the marginal rate paid on the income of the owner of the firm, τ_t^P , is equal to $\bar{\tau}_t^P + (\partial \bar{\tau}_t^P / \partial \text{div}_t)\text{div}_t$. Note that it is evident from condition (8) that $Y_L = w$. Therefore, at the margin personal taxes (and the corporate tax) do not affect the decision on how much labor to hire.

On the contrary, condition (9) suggests that personal taxes *reduce* the cost of adding an additional unit to the capital stock: leaving \$1 in the firm reduces dividends net of tax received by only $1 - \tau_t^P$ dollars, and that is why it differs from Eq. (23) by a factor of $1 - \tau_t^P$. However, to determine the effect of personal taxes on the user cost of capital, it is also necessary to include the benefit of adding an additional unit of capital, which is given

¹⁴ This is equivalent to assuming that at the time \$1 is invested, the firm goes to a bank, borrows against the future tax saving generated by the debt and discounts for depreciation and pays dividends with the borrowed funds.

¹⁵ Moreover, this simplification does not affect results when the marginal rate paid on income remains constant over time.

by the shadow price of capital, λ_t . To do this, we start by differentiating the condition (9) with respect to time, obtaining

$$\dot{\lambda}_t = \left[-r + \frac{d}{dt} \log(1 - \tau_t^P) + \frac{\dot{p}_t}{p_t} \right] \lambda_t.$$

Substituting in Eq. (10) and rearranging one obtains

$$Y_K = \frac{[1 - \tau(b + z)]}{1 - \tau} \left[\left\{ r + \rho - \frac{d}{dt} \log(1 - \tau_t^P) \right\} p_t - \dot{p}_t \right] \equiv v_t^{NV}, \quad (11)$$

where v_t^{NV} denotes the user cost of capital when firms take into account the marginal rates their stockholders pay (cost *without veil*). Expression (11) differs from Eq. (3) only in one term, $-(d/dt)\log(1 - \tau_t^P)$, which reflects the changes in the marginal rate of the owner over time. These can be broken into two components: the first one captures the changes that originate in variations in the individual's income level, $(\partial \bar{\tau}_t^P / \partial \text{div}_t)(d(\text{div}_t)/dt)/(1 - \tau_t^P)$, and the second reflects exogenous changes in the structure of marginal rates, $(d\tau_t^P/dt)/(1 - \tau_t^P)$. Thus, the first term depends on the dividend policy chosen by the firm while the second can be interpreted as the expectation of how much the marginal rate will change in the next instant.

Two results follow from Eq. (11). First, when the marginal rate does not change over time, the user cost is independent of the personal tax and equal to v^V . What is the intuition? It can be seen from condition (10) that the personal tax reduces the benefit of investing an additional unit of capital in t by a factor of $(1 - \tau_t^P)$. When $(d/dt)\log(1 - \tau_t^P) = 0$, this cancels out exactly the lower cost of leaving \$1 in the firm and retiring it one instant later, and personal taxes do not affect the desired capital stock. This result is more general. Note that personal taxes are paid only when the firm pays dividends. In that sense, it differs from the corporate tax, which is paid as soon as taxable profits accrue. Since taxable profits do not necessarily coincide with economic profits in present value, the corporate tax affects the desired capital stock. By contrast, the personal tax is proportional to profits paid and therefore it does not affect the problem's optimality conditions or the desired capital stock.

The second result—closely related to first—is that personal taxes affect the user cost only when the marginal rate paid on dividends changes over time, either because the optimal dividend policy changes the tax bracket of the firm's owner, or because the marginal rate changes exogenously over time. For example, if the marginal rate is falling at t , the cost of postponing dividends falls, because the marginal rate will fall in the future. This implies a lower user cost. The opposite occurs when the marginal rate increases over time. Consequently, personal taxes affect the desired capital stock only when a change in marginal rates is expected in the immediate future, or when the owners of the firm change their tax bracket over time because of variations in their income. In the model presented here, this can only occur if the owner of the firm chooses a dividend policy that makes his marginal rate vary. But more generally, the change will also depend on the evolution of the rest of his income. For example, if the rest of his income increases over time and that pulls him into a higher tax bracket, the

user cost will be higher, which, *ceteris paribus*, will make him postpone investments. However, the model suggests that the effect of personal taxes on the desired capital stock is small, because major changes in income tax rates (“tax reforms”) are infrequent and bracket changes, besides averaging out over time, only will be relevant for entrepreneurs or stockholders with relatively low income, since the rest are always in the top bracket.

3. Estimation

In this section we derive the estimation equation that relates the capital–output ratio to the user cost of capital (both with and without a corporate veil) and the long-run elasticity of substitution between capital and labor. Our dependent variable is the capital–output ratio, and the investment–capital ratio common in earlier empirical implementations of the neoclassical model. We use Bertola and Caballero’s (1990) cointegration argument to estimate a well defined long-run elasticity of capital that does not depend on the specifics of the adjustment cost structure. All we need is that desired and actual capital be nonstationary, while the difference between (the logs of) both variables is stationary.

At all times, we can obtain the desired capital stock as a function of the user cost from Eq. (3) or from Eq. (11). To estimate this function, it is necessary to specify the functional form of Y . The production function is assumed to have constant elasticity of substitution (CES), so $Y_{K,t} \equiv \alpha(K_t/Y_t)^{-1/\sigma}$, where $-\sigma$ is the elasticity of substitution (thus $\sigma > 0$), Y_t is the production level, and α is the distribution parameter. Substituting into Eq. (3) (or Eq. (11)) yields

$$K_t = \left(\frac{v_t}{\alpha}\right)^{-\sigma} Y_t,$$

where it follows that

$$\log \frac{K_t}{Y_t} = \sigma \log \alpha - \sigma \log v_t, \tag{12}$$

an equation that can be estimated econometrically with series of K , Y and v .

Nevertheless, the variable K_t , which appears in Eq. (12), is the capital stock firms desire, which is not observable if there are adjustment costs. To replace K_t with an observed variable, we apply the cointegration argument of Bertola and Caballero (1990). We denote the observed capital stock by K_t^{obs} , and define ε_t by

$$\varepsilon_t \equiv \log K_t^{\text{obs}} - \log K_t, \tag{13}$$

where ε_t captures transitory discrepancies between both capital measures due to adjustment costs. Substituting Eq. (13) in Eq. (12) yields:

$$\log \frac{K_t^{\text{obs}}}{Y_t} = \sigma \log \alpha - \sigma \log v_t + \varepsilon_t. \tag{14}$$

The economic interpretation of ε_t allows us to assume both capital measures cointegrate so that estimating Eq. (14) by OLS gives a consistent estimator of the long-run substitution rate between capital and labor, σ .¹⁶

In principle, Eq. (14) can be estimated with aggregate data from National Accounts or with information from firms. However, in the case of Chile, it is not possible to use data from National Accounts because no series of the private product and the aggregate private capital stock is available. Therefore, we estimated Eq. (14) using a panel of publicly held firms, those that published the Standardized Quarterly Financial Reports (Spanish acronym: FECUs) between 1985 and 1995.¹⁷

If firms ignore personal taxes in their decisions, the user cost of capital to firm i in period t will be

$$v_{it}^V = \frac{[1 - \tau_t(b_i + z_{it})]}{1 - \tau_t} [(r_t + \rho)p_t - \dot{p}_t],$$

(see Eq. (3)). On the other hand, if the marginal rates paid by their stockholders are considered, the user cost of capital is

$$v_{it}^{NV} = \frac{[1 - \tau_t(b_i + z_{it})]}{1 - \tau_t} \left[\left\{ r_t + \rho - \frac{d}{dt} \log(1 - \tau_t^p) \right\} p_t - \dot{p}_t \right].$$

It should be noted that the user cost varies among firms (due to the b_i and z_{it} terms) and over time.¹⁸ Then we will have

$$\log \frac{K_{it}^{\text{obs}}}{Y_{it}} = \alpha_{0i} - \sigma \log v_{it}^* + \varepsilon_{it}, \quad (15)$$

where α_{0i} is equal to the sum of $\sigma \log \alpha_i$ and a constant equal to the average difference between the logarithms of capital stocks with and without adjustment costs¹⁹ and * in v_{it}^* is equal to V in the case with veil and equal to NV in the case without veil.

To test for a corporate veil, we estimate the following model:

$$\log \frac{K_{it}^{\text{obs}}}{Y_{it}} = \alpha_{0i} - \sigma [\theta \log v_{it}^V + (1 - \theta) \log v_{it}^{NV}] + \varepsilon_{it}. \quad (16)$$

Parameter θ can be interpreted as the fraction of change in the capital–output ratio that is due to changes in the user cost with veil. As a result, a fraction $(1 - \theta)$ of these are due to changes in the user cost without veil.

¹⁶ Both series of (log) capital can differ on average by a constant, so the estimated value of the constant does not converge to $\sigma \log \alpha$. Note also that this argument makes it possible to rigorously derive an error term for the regressions that follow.

¹⁷ Data previous to 1985 is not considered, because the only consistent series of the price of capital begins in 1985. There is a previous series which begins in 1977, but the differences with the more recent one are significant, and analysts generally consider the revised series to be significantly more accurate.

¹⁸ The reason we do not permit parameter b to vary over time for a specific firm is that the proxy available to us for this variable is not very accurate, leading us to work with its average over the sample years.

¹⁹ See footnote 16.

The preceding formulation incorporates fixed effects (the α_{0i} parameters), because the intensity of capital use varies across firms; for example, *ceteris paribus*, the capital–output ratio is higher for a steel mill than it is for a supermarket.

We will consider two possibilities for parameter σ . First, we will assume it is constant in the sample, and then we will let it vary across the eight sectors (at two CIU digits) included in the sample. On the other hand, parameter θ will be assumed to be common to all firms.

For a description of the sources of data used in estimations, see Appendix B.

4. Results

4.1. What results can be expected?

Before reporting the results from estimations, it is advisable to look at the data. Fig. 1 shows the average (of the firms) of v_{it} for the 11-year period with and without veil. The two costs differ in three years (1987, 1993 and 1994).²⁰ In 1987, the top marginal tax rate had its sharpest decline, from 0.56 to 0.50. In both cases, the highest user cost of capital during the period is 0.225; the minimum value with veil is 0.153 and 0.048 without veil.

To determine the source of variations in the user cost with veil, Fig. 2 breaks its logarithm into three components (indicated in the figure as Comp. 1, Comp. 2 and Comp. 3, respectively):

$$\log v_{it}^V \equiv \log \frac{1 - \tau_t(b_i + z_{it})}{1 - \tau_t} + \log p_t + \log \left(r_t + \rho - \frac{\dot{p}_t}{p_t} \right). \tag{17}$$

To facilitate the comparison, the average value has been subtracted from each component in the figure. Note that only the first term depends on the corporate tax rate. Fig. 2 is categorical: variations in the user cost are basically caused by changes in the relative price of capital and the interest rate.²¹ By contrast, the first term in Eq. (17) shows a much smaller variation. Since the desired capital stock depends on the corporate tax rate only through the user cost of capital, the conclusion is that most of the fluctuations in the demand for capital do not come from variations in the corporate tax rate. Fig. 2 shows the breakdown of the variance of $\log v_{it}^V$ into the variance and covariance of the three components. The sum of the

²⁰ When testing whether a corporate veil exists, one may be concerned because the two measures differ only in three years. Nevertheless, note that our panel includes 83 firms. Thus we have 249 data points (27% of the total sample) to estimate whether there is a corporate veil. Also note that since the user cost proxies we use vary across firms, among other things due to differences in their capital composition, we do indeed have significant variation in our right-hand-side variable.

²¹ If the user cost without veil is considered, there is also an important contribution from the variations in the marginal personal tax rate.

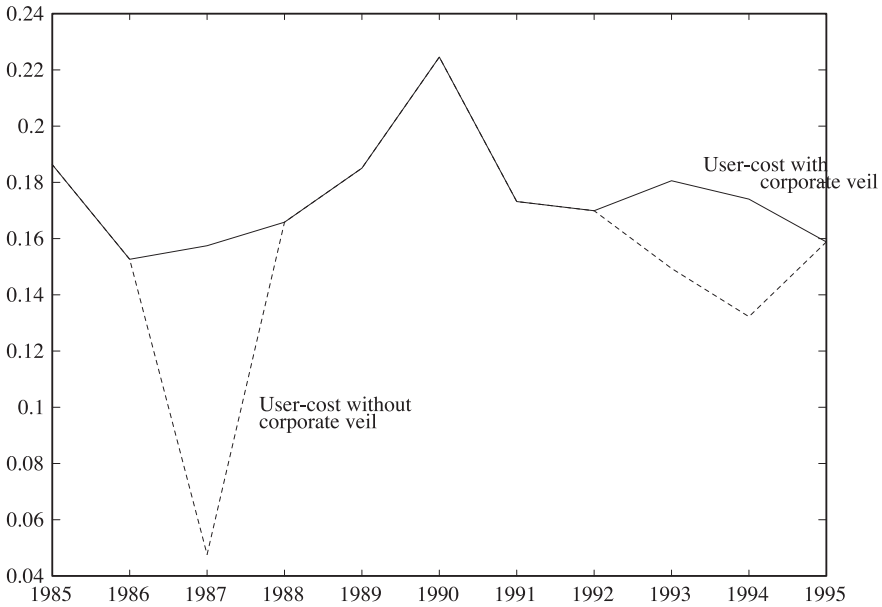


Fig. 1. Average user cost of capital. The figure shows the average (simple) annual user cost of capital between 1985 and 1995 for the 83 firms in the sample, with and without corporate veil.

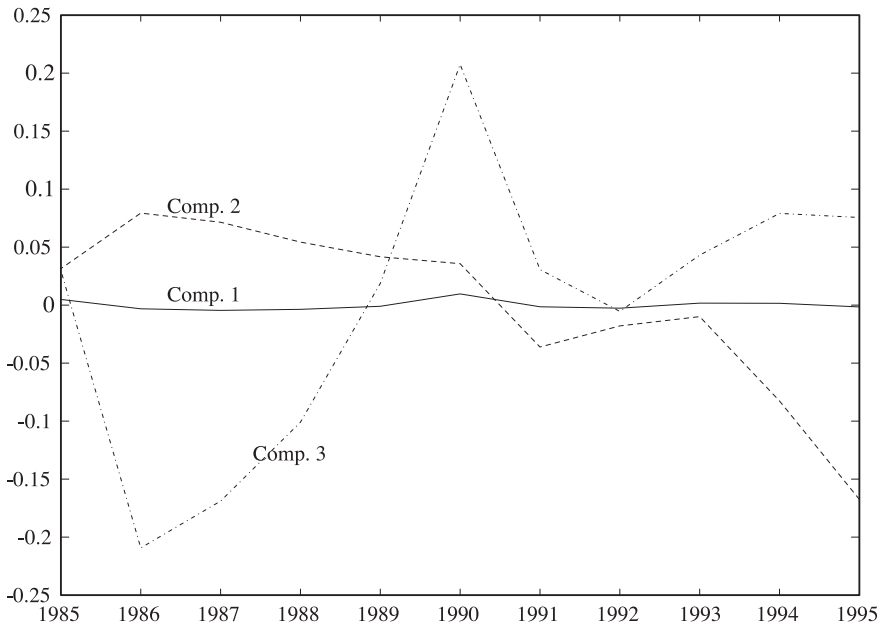


Fig. 2. Breakdown of the logarithm of the user cost of capital. The figure shows the three components of the user cost of capital with corporate veil. Logarithms have been broken down as in the text, between 1985 and 1995.

Table 2
Breakdown of variance

Component	Share (%)
Comp. 1: Tax	0.16
Comp. 2: Price of capital	48.53
Comp. 3: Interest rate and \dot{p}	125.07
2Cov(Comp. 1,Comp. 2)	-0.19
2Cov(Comp. 1,Comp. 3)	7.03
2Cov(Comp. 2,Comp. 3)	-80.60
Total:	100.00

Contribution by component to the variance in the user cost without veil. Comp. 1 = $\log[(1 - \tau_t(b_i + z_{it})) / (1 - \tau_t)]$; Comp. 2 = $\log p_t$; Comp. 3 = $\log(r_t + \rho - (\dot{p}_t/p_t))$.

variance of the first component (where the corporate tax rate matters) and the covariances of that component with the other two explain only 7% of the total variance (Table 2).

Fig. 3 shows another interesting aspect: the average value (weighted by the firms' assets) of $b_i + z_{it}$ is near 1—in fact, slightly above 1—throughout the period under consideration. It fluctuates between 0.99 in 1990 and 1.12 in 1995. The simple average—which corresponds to the dotted line in the figure—takes values even closer

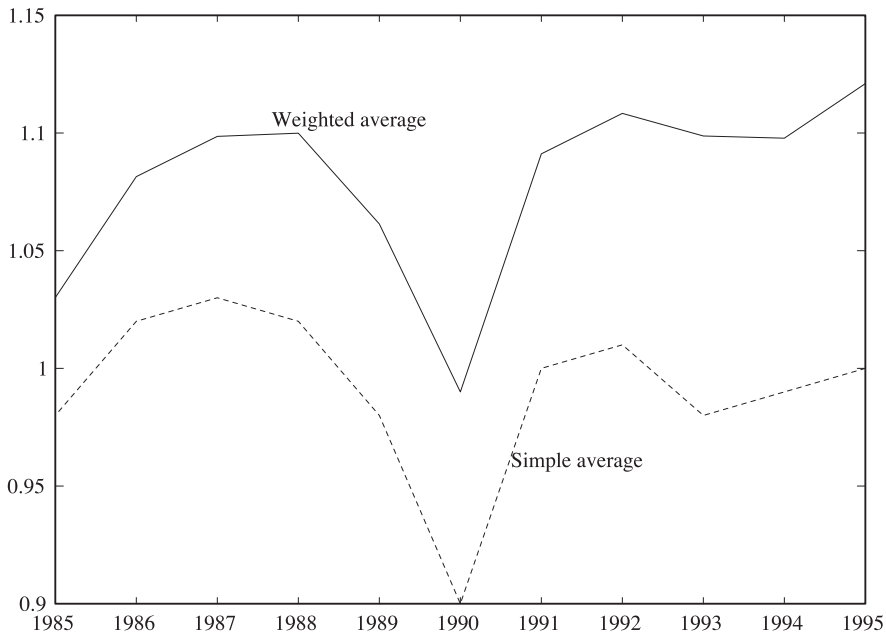


Fig. 3. Average values of $b + z$. The figure shows weighted (by firms' assets) and simple averages of $b_i + z_{it}$ for the 83 firms in the sample, between 1985 and 1995.

Table 3
Model with common σ

Parameter	Simple	1 Lead	1 Lag
σ	0.18 (0.04)	0.42 (0.14)	0.14 (0.07)
θ	0.93 (0.30)	1.06 (0.26)	0.75 (0.61)

Estimation for a group of 83 firms, fixed effects, annual data, 1985–1995, by WLS with the respective weights estimated in the first stage with OLS and with a Cochrane–Orcutt correction with a self-correlation parameter common to all firms. The delta method was used to get the standard deviations of σ and θ from the standard deviations of the linearly estimated parameters ($\sigma\theta$ and $\sigma(1-\theta)$). Standard deviations are in parentheses. The “Simple” column refers to the estimate of model (16). Columns “1 Lead” and “1 Lag” consider corrections for bias in small samples of a lag and a lead, respectively, of the user cost logarithm with and without veil.

to 1. This suggests that even larger changes of the corporate tax rate should not have significantly affected user cost and aggregate capital stock.

As we will see later, our econometric results corroborate this conjecture.

4.2. Regressions

The second column of Table 3 shows the estimated parameters when σ and θ are assumed to be the same across firms in Eq. (16). The estimated value of σ was 0.18 with a standard deviation of 0.04. On the other hand, the estimated value of θ was 0.93, with a standard deviation of 0.30.

The presence of adjustment costs implies that in small samples the estimated values of σ will be biased towards zero (Caballero, 1994).²² To correct this bias, either leads or lags of the independent variables considered are added to the regressors. The third and fourth columns show the coefficients estimated this way. The estimated value of σ grows significantly when a lead is incorporated,²³ rising to 0.42 with a standard deviation of 0.14. It should also be noted that estimated values of θ remain near 1.

The magnitude estimated for the elasticity of substitution indicates that changes in the user cost may significantly affect the desired capital stock. To get an idea of the relevant orders of magnitude, consider the example of a firm with a user cost equal to 0.225 (the average of v_{it}^V in 1990), a capital–output ratio equal to 2.64 (the aggregate ratio in 1990),²⁴ and sales of \$100 million/year. Since the relative price of capital in 1990 is $p_{90}=0.926$, the firm’s desired capital stock is \$244.5 million.²⁵ If the user cost drops

²² Note that this does *not* contradict the statement made previously, according to which the estimators in question are consistent, since the latter property is asymptotic (big samples).

²³ Unlike Caballero (1994) where this happens when a lag is incorporated. It may be because our proxy for the b_i in period t includes information from the whole period in our sample. It was necessary to work with this proxy to avoid the big fluctuations in annual values of this variable.

²⁴ In other words, $\sum_i K_{i90}^{\text{obs}} / \sum_i Y_{i90}$.

²⁵ \$244.5 million = \$100 million \times 2.64 \times 0.926.

Table 4
Capital stock and corporate tax

Corporate tax	Capital stock 1990	Capital stock 1995
0%	100	100
5%	99.97	100.25
10%	99.93	100.54
15%	99.90	100.87
20%	99.88	101.25

Variation of the aggregate desired capital stock. Desired stock when $\tau=0$ has been normalized to 100.

10% to 0.202, production remains constant, and the elasticity of substitution is $\sigma=0.42$, the capital stock desired by the firm will grow 4.2% or \$10.3 million to \$254.8 million.²⁶

However, the fact that the elasticity of substitution is considerable does not mean that variations in the corporate tax rate affect the desired long-run capital stock very much, because its impact will depend on the magnitude of b_i+z_{it} . In fact, for our sample of firms the effect is very small. The second column of Table 4 shows how the sum of the capital stocks desired by firms varies (i.e., how our measure of aggregate capital stock varies) with the corporate tax rate in 1990. (To make it easier to read, we have made the aggregate capital stock that would have been demanded, had the corporate tax rate been 0, equal to 100.) Note that when $\tau=0.2$ the desired capital stock is only 0.12% lower than when $\tau=0$. In other words, for the levels usually referred to in discussions about the ideal corporate tax rate, the effect is very small. The third column of Table 4 repeats the exercise for 1995. The novelty in this case is that the higher the tax rate the more capital stock is desired ($z>1$); but, in any case, the effect is still small.²⁷

What explains this apparently counterintuitive result, that higher taxes can lead to a higher desired capital stock? As seen in Fig. 3, the average annual value of b_i+z_{it} is near 1. In fact, in 1990 this sum varies from a minimum of 0.43 and a maximum of 1.47, with an average of 0.90 (standard deviation of 0.28).²⁸ Therefore, it is not surprising that the aggregate effect is very small, because, as we have already mentioned, when $b_i+z_{it}=1$ the desired capital stock does not depend on τ . Moreover, the fact that some firms are bigger than others and that there is a positive correlation in the data between firm size and $b_i+z_{it}>1$ indicates it is possible that an increase in τ may lead to higher desired capital stock.²⁹ Finally, note that even though our results indicate that the aggregate capital stock should not vary significantly when τ changes, the dispersion of b_i+z_{it} suggests that in many firms the corporate tax has a bigger effect than the aggregate figure might suggest.

²⁶ Hereafter, all the exercises will suppose we are moving throughout the same isoquant.

²⁷ The demand for capital will increase, albeit slightly, after an increase in τ in 10 of the 11 years considered in our sample.

²⁸ In the case of 1995 the minimum is 0.56 and the maximum is 1.53, with an average of 1.00.

²⁹ It follows from Fig. 3 that the weighted average of b_i+z_{it} is larger than 1 in 10 of the 11 years considered in the sample.

Table 5

Model breaking down the logarithm of the user cost into three components

Parameter	Simple	1 Lead	1 Lag
σ_1	0.34 (0.05)	0.39 (0.06)	0.38 (0.06)
σ_2	0.63 (0.03)	0.74 (0.04)	0.69 (0.03)
σ_3	0.31 (0.11)	0.31 (0.08)	0.31 (0.08)

Results of the estimation of Eq. (18). The used sample and estimation techniques are the same of Table 3. Standard deviations are in parenthesis.

It is interesting to note that the estimated value for θ is close to 1 (0.93 and 1.06, respectively, in the simple and one-lead regressions). This suggests that there is a corporate veil in Chile—personal tax rates do not seem to affect the demand for capital.

4.3. Robustness

To check whether the explanatory power of the user cost term mainly comes from changes in prices and the interest rate, Eq. (16) was reestimated for the case with corporate veil, but this time separating the contributions of the three components that make up the user cost:

$$\log \frac{K_{it}^{\text{obs}}}{Y_{it}} = \alpha_{0i} - \sigma_1 \log \frac{1 - \tau_t(b_i + z_{it})}{1 - \tau_t} - \sigma_2 \log p_t - \sigma_3 \theta \log \left(r_t + \rho - \frac{\dot{p}_t}{p_t} \right) - \sigma_3 (1 - \theta) \log \left(r_t + \rho - \frac{\dot{p}_t}{p_t} - \frac{d}{dt} \log(1 - \tau_t^p) \right). \quad (18)$$

Table 5 shows the results, which indicate that $b+z$ plays a significant role in estimating σ in Table 3. Actually, in the case with a correction with a lead, an estimated value of σ_1 of 0.38 is obtained, which does not differ greatly from the one obtained by making all the σ_i equal (Table 3).³⁰

Finally, Table 6 shows the estimated coefficients when variations of σ are allowed across sectors at the two-digit level. The second column shows the estimated parameters for the group of 83 firms, using nonlinear weighted least squares, with the respective weights estimated in the first stage with homoscedastic errors. The nonlinear parameter is θ . Fixed effects and the Cochrane–Orcutt correction with an autocorrelation parameter common to all the firms are considered. The third and fourth columns show the results when a lag and a lead are incorporated, respectively, to correct the bias in the estimated values of σ . Standard deviations are indicated in parentheses.

³⁰ Moreover, estimated values of σ_1 are more stable among specifications than the ones of σ .

Table 6
Model with sectoral σ

Parameter	Simple	1 Lead	1 Lag
σ Agriculture and fishing	-0.31 (0.21)	0.71 (0.35)	0.02 (0.32)
σ Mining	0.18 (0.37)	1.60 (0.46)	0.68 (0.52)
σ Manufacturing	0.22 (0.06)	0.59 (0.10)	0.16 (0.09)
σ Electricity, gas and water	0.32 (0.08)	0.51 (0.07)	0.50 (0.06)
σ Retail	0.32 (0.21)	0.74 (0.28)	0.56 (0.24)
σ Transportation and communications	0.11 (0.16)	0.48 (0.15)	-0.19 (0.21)
σ Finance, insurance, etc.	0.09 (0.06)	0.14 (0.08)	0.11 (0.08)
σ Communal, social and personal services	0.18 (0.08)	0.15 (0.12)	-0.11 (0.11)
σ Average	0.14	0.62	0.22
θ	0.93 (0.04)	0.82 (0.05)	1.01 (0.04)

Estimation for a group of 83 firms, fixed effects, annual data, 1985–1995, by WLS with the respective weights estimated in the first stage with OLS and with a Cochrane–Orcutt correction with a self-correlation parameter common to all firms. Standard deviations are in parentheses. The “Simple” column refers to the estimate of model (16). Columns “1 Lead” and “1 Lag” consider corrections for bias in small samples of a lag and a lead, respectively, of the user cost logarithm with and without veil.

Again, elasticities are larger when working with a lead to correct the small sample bias.³¹ The comments that follow refer to this case. The largest (absolute) elasticity of substitution between capital and labor is obtained in the mining sector, where it is 1.60, whereas the lowest elasticities are in the financial and service sectors, which are estimated at 0.14 and 0.15, respectively. The estimated value of θ varies between 0.82 (when working with a lead) and 1.01 (when working with a lag) thus confirming the findings in Table 3. As before, this suggests the existence of a corporate veil in Chile.

5. Conclusion

Theory does not support the widely held belief that firms’ desired capital stock is lower when corporate or personal taxes are higher. Informed policy discussion should recognize that depreciation allowances and interest discounts compensate for the lower returns brought about by higher corporate taxes. In fact, when the present value of the discounts is higher than the cost of the capital good, higher corporate tax rates *reduce* the user cost and *increase* the desired capital stock.

Empirically, we found that corporate taxes affect the user cost of capital and the desired capital stock very little because Chilean tax law allows discounts for interest and depreciation. For the average of the firms considered in this paper, the discounts are close to the cost of capital goods, in present value.

³¹ Also in OLS regressions (second column) and with a lag (fourth column), there are estimated values of σ with the wrong sign, which does not occur when working with a lead.

We have also shown that, theoretically, personal tax rates affect the user cost and desired capital stock only when stockholders expect their marginal rate to change from one period to another. Empirically, however, we could not detect any effect of changes in personal taxes on the desired capital stock—there is evidence of a corporate veil.

The preceding implies that the aggregate desired capital stock is not sensitive to variations in the corporate tax rate. But it is sensitive to changes in the user cost of capital nonetheless. In fact, using a group of 83 firms with annual data between 1985 and 1995 we found that the average (across sectors) elasticity of substitution between capital and labor is 0.62. In the end, variations of the relative price of capital goods and the interest rate affect the user cost of capital much more than tax rates in Chile.

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Appendix A. Proofs

A.1. Derivation of Eq. (3)

Before solving the firm's problem, it is convenient to rewrite the objective function (2) as

$$\int_0^{\infty} e^{-rt} \{ (1 - \tau) [Y(K_t, L_t) - wL_t] - [1 - \tau(b + z)] p_t I_t \} dt, \quad (19)$$

where $b_t p_t I_t = r b p_t I_t \int_t^{\infty} e^{-r(s-t)} ds$. We have also used the two following identities (which are derived later in Appendix A):

$$\int_0^{\infty} e^{-rt} r D_t dt \equiv \int_0^{\infty} e^{-rt} b p_t I_t dt; \quad (20)$$

$$\int_0^{\infty} e^{-rt} \Delta_t dt \equiv \int_0^{\infty} e^{-rt} z p_t I_t dt. \quad (21)$$

It is important to note the equality between Eqs. (2) and (19) does not imply the integrands are equal. The advantage of Eq. (19) lies in the fact it does not include values of I

preceding t , unlike Eq. (2); in that case, both D_t and Δ_t involve investments made before t so the Hamiltonian method cannot be used to solve the dynamic optimization problem. The Hamiltonian associated with Eq. (19) is

$$H \equiv e^{-rt} \{ [(1 - \tau)[Y(K_t, L_t) - wL_t] - [1 - \tau(b + z)]p_t I_t \} + \lambda_t (I_t - \rho K_t).$$

where λ_t is the shadow price of capital. The first-order conditions are

$$\frac{\partial H}{\partial L} \equiv e^{-rt} (1 - \tau)(Y_L - w) = 0, \tag{22}$$

$$\frac{\partial H}{\partial I} \equiv -e^{-rt} [1 - \tau(b + z)]p_t + \lambda_t = 0, \tag{23}$$

$$\frac{\partial H}{\partial K} + \dot{\lambda}_t \equiv e^{-rt} (1 - \tau)Y_K - \rho\lambda_t + \dot{\lambda}_t = 0. \tag{24}$$

Condition (22) says that at all times labor will be hired until its marginal product is equal to the wage. Note that the corporate tax rate does not affect the labor hiring decision.

Condition (23) gives the optimal amount of investment. The benefit of adding one unit of capital to the stock at t is λ_t , the shadow value of one unit of capital. The cost of adding that unit at t is the present value of the interest that has to be paid for that debt, $[1 - \tau]bp_t$, plus the profits that have to be retained to finance the purchase of that unit of capital, $[1 - b]p_t$, minus the present value of the discounts for depreciation that can be made for the unit of capital bought at t , τz .

Finally, we analyze condition (24) in greater detail. To do that, we note first that totally differentiating condition (23) with respect to time gives

$$\dot{\lambda}_t = \left(\frac{\dot{p}_t}{p_t} - r \right) \lambda_t.$$

Substituting in Eq. (24) implies that at the optimum

$$(1 - \tau)Y_K - [1 - \tau(b + z)][(r + \rho)p_t - \dot{p}_t] = 0.$$

Rearranging, it follows that at all times t

$$Y_K = \frac{[1 - \tau(b + z)]}{1 - \tau} [(r + \rho)p_t - \dot{p}_t] \equiv v_t^Y.$$

Proposition 1. $\int_0^\infty e^{-rt} r D_t dt \equiv \int_0^\infty e^{-rt} b p_t I_t dt$

Proof: Writing D_s explicitly gives

$$\int_0^\infty e^{-rt} r D_t dt = r \int_0^\infty e^{-rs} \left[\int_0^s b p_t I_t dt \right] ds.$$

Making a change of variable for the second integral (Tonelli’s Theorem) gives

$$\int_0^\infty \left[\int_t^\infty e^{-rs} p_t I_t ds \right] dt.$$

Finally, factorizing the second integral by $e^{-rt} p_t I_t$, one obtains

$$rb \int_0^\infty e^{-rt} p_t I_t \left[\int_t^\infty e^{-r(s-t)} ds \right] dt,$$

which can be written as the product of two integrals:

$$b \int_0^\infty e^{-rt} p_t I_t dt \times r \int_t^\infty e^{-r(s-t)} ds,$$

and as $\int_t^\infty e^{-r(s-t)} ds = \frac{1}{r}$ one gets

$$\int_0^\infty e^{-rt} b p_t I_t dt,$$

which was what we wanted to prove. □

Proposition 2. $\int_0^\infty e^{-rt} \Delta_t dt = \int_0^\infty e^{-rt} z p_t I_t dt$

Proof: Rewriting Δ_t the expression $\int_0^\infty e_t^{-rt} \Delta_t dt$ is

$$\int_0^\infty e^{-rt} \left[\int_0^t \delta_{t-s} p_s I_s \right] ds.$$

Changing variables in the second integral leads to

$$\int_0^\infty \left[\int_0^\infty \delta_s e^{-r(s+t)} p_t I_t ds \right] dt.$$

Factorizing the second integral by $e^{-rt} p_t I_t$, the expression is

$$\int_0^\infty \left[\int_0^\infty \delta_s e^{-rs} ds \right] e^{-rt} p_t I_t dt = \int_0^\infty z e^{-rt} p_t I_t dt,$$

because $\int_0^\infty \delta_s e^{-rs} ds \equiv z$ □

Appendix B. The data

As mentioned, estimates were made using a group of publicly held firms that issued Standardized Quarterly Financial Reports (Spanish acronym: FECUs) between 1985 and 1995. No information prior to 1985 was considered, because the recent review of capital

Table A1
Corporate tax rates

Year	τ_{1a}	τ_a	τ
1985	0.10	0.15	0.24
1986	0.10	0	0.10
1987	0.10	0	0.10
1988	0.10	0	0.10
1989	0	0	0
1990	0.15	0	0.15
1991	0.15	0	0.15
1992	0.15	0	0.15
1993	0.15	0	0.15
1994	0.15	0	0.15
1995	0.15	0	0.15

τ_{1a} is the First Category tax; τ_a is the Additional tax that was in effect only in 1985 and $\tau = 1 - (1 - \tau_{1a})(1 - \tau_a)$ is the corporate tax.

prices by the Central Bank, which involved important changes, only covered the period starting in 1985. FECUs were obtained from the Santiago Stock Exchange. The group includes 83 firms that published FECUs during each one of the 11 years (which we call “continous firms”). The following information was also extracted from the FECUs:

Capital stock (K_{it}^{obs}): Corresponds to fixed assets in the balance sheet deflated by the price of capital obtained from the National Accounts.

Production (Y_{it}): Corresponds to operating income from each firm’s income statement deflated by the implicit GDP deflator.

Fraction of gross investment financed with debt (b_i): The average value over the sample of the debt/asset ratio was used for each firm; the information was obtained from each firm’s balance sheet.³²

The remaining variables necessary to make estimates were obtained from the following sources:

Interest rate (r_t): Corresponds to the average interest rate for loans in the banking system. It was obtained from the *Monthly Bulletin* of the Central Bank.³³

Economic depreciation of capital (ρ): It was assumed equal to 10%.

Present value of discounts for depreciation (z_{it}): The fraction of economic value that can be discounted as cost at present value is calculated from the expression

$$z = \int_0^T \frac{e^{-rs}}{T} ds = \frac{(1 - e^{-rT})}{rT}.$$

where T is the period of depreciation of the asset. According to tax law, different assets have different periods of linear depreciation. Raddatz (1997) estimated the period of

³² Other proxies were tested like debt/equity, obtaining more irregular series (including negative values).

³³ As of 1990, a group of Chilean firms used foreign debt to finance their investments. To test the significance of this fact, estimates were made assuming that a fraction of the firms μ (unknown) would have been financed at LIBOR + risk premium as of that year. μ was considered constant and varying annually, and the breakdown was maintained for firms with and without corporate veil. The values estimated for μ were not significant and the estimated substitution rate between capital and labor was, in general, lower than the rates reported in the paper, which explains why only results considering domestic financing are presented.

depreciation of three categories of assets, buildings (15 years), machinery and equipment (3 years), and vehicles (3 years). A different z was calculated for each of the three kinds of assets described above, and then, using the FECU of each firm, the fraction of assets in each one of the categories for each year was calculated.

Relative price of capital (p_t): This is the quotient of the capital stock deflator and the GDP deflator. It was obtained from the National Accounts prepared by the Central Bank of Chile, revised in 1998.

Expected variations in the price of capital (\dot{p}_t): Each year, the average of the variations of $\log p$ in preceding years was taken as a prediction of the following \dot{p}/p . This assumption is consistent with assuming that the $\log p$ series follows a random walk, an assumption consistent with the data.

Corporate tax (τ): This tax corresponds to what a firm pays when it retains \$1 of profits. It is a function of two specific tax rates, the First Category tax rate, τ_{1a} and the Additional tax rate,

$$\tau = 1 - (1 - \tau_{1a})(1 - \tau_a).$$

The information to build this series was obtained from Lehmann (1991) and the Internal Revenue Service. Table A1 shows the series of the corporate tax rates.

Personal tax (τ_t^P): The top marginal rate of the income tax, τ_t^{Max} , were taken, discounting credits received in the same period of time for the First Category and the Additional tax, and it was assumed the owner of the firm is informed at least 1 year in advance of any changes in the rate.³⁴

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³⁴ The fact that credits for the first category tax and the additional rate are not modified when there are changes in rates simplifies the respective calculations, where $(d\tau_t^P/dt)$ is equal to $(d\tau_t^{\text{Max}}/dt)$.

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