The Neoclassical Theory of Firm Investment and Taxes: A Reassessment *

Gabriel Chodorow-Reich
Harvard University

Abstract

Economists have widely varying opinions of how corporate taxation affects aggregate investment, output, and wages. This disagreement reflects a 60-year history of misapplication of the neoclassical theory of investment to interpret empirical work and guide policy analysis. In this article I reconsider the accumulated evidence relating tax policy to firm investment through the lens of the neoclassical theory. Empirical work suggests a range for the firm-level, short-run semi-elasticity of the investment-to-capital ratio to the user cost of -0.25 to -0.75. The mid-point of this range translates into values for the elasticity of firm revenue to capital of between 0.22 and 0.35. The implied general equilibrium, long-run elasticity of capital to the user cost can differ substantially from leading policy models. The elasticity of the wage to the user cost ranges from -0.3 to -0.7, or from -0.1 to -0.2 for changes to the user cost in the C-corporate sector alone. In the relatively low-tax regime in the U.S. in 2024, the neoclassical contribution to higher output from higher capital cannot rationalize more than modest dynamic tax revenue offsets from further reductions in corporate taxation.

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1 Introduction

Studies of how tax incentives affect investment stretch back more than 60 years to the seminal analysis of the investment decision of a profit-maximizing firm in Jorgenson (1963) and Hall and Jorgenson (1967). Jorgenson (1963) derives the user cost of capital and shows that under a Cobb-Douglas production function the firm's "desired" or long-run capital stock satisfies $K = \alpha Y/R$, where K is the stock of capital, Y is the firm's revenue, R is the user cost, and α is the revenue elasticity of capital. Hall and Jorgenson (1967) measure R incorporating a detailed analysis of the corporate tax code and conduct counterfactual exercises for the effect of tax reforms on investment. In their framework, the long-run elasticity of capital to the user cost is -1, which Council of Economic Advisers (2019, p. 59) refers to as the "neoclassical benchmark."

A wave of empirical papers have estimated a user cost elasticity. Hassett and Hubbard (2002, p.1321) summarize the evidence as finding "elasticities of investment to the user cost of capital between -0.5 and -1.0," a range that has become enshrined in evaluations of tax policy (Congressional Budget Office, 2018*b*; Council of Economic Advisers, 2019, 2025). Yet, this apparently happy confluence of theory and empirics has not been fully persuasive. A poll of economists taken five years after the 2017 Tax Cuts and Jobs Act (TCJA) found that 30% of respondents agreed with the statement that the corporate capital stock was substantially higher as a result, 33% disagreed, and 36% were uncertain (Clark Center for Global Markets, 2023). In their prospective analysis of TCJA, Barro and Furman (2018) used an elasticity of -1.6, outside of the Hassett and Hubbard (2002) range or the supposed neoclassical benchmark.

This paper contends that this disagreement reflects a 60-year history of mis-application of the neoclassical theory of investment to interpret empirical work and guide policy analysis. This history starts with the statement that the long-run elasticity of capital to the user cost in the neoclassical framework is -1. That error was first shown in a comment by Coen (1969). The reasoning is simple. Jorgenson (1963) and Hall and Jorgenson (1967) obtain $\partial \log K/\partial \log R = -1$ only by holding firm revenue Y fixed. But lower capital induced by an increase in the cost of capital will also reduce firm revenue, resulting in an "accelerator" feedback effect from lower revenue into even lower capital that the analysis of tax reforms in Hall and Jorgenson (1967) omits.

Empirical studies of the "user cost elasticity of investment" have implemented a diverse set of

empirical specifications that connect to different structural objects. These include the magnitude of adjustment costs, the elasticity of investment inclusive of the feedback effect identified by Coen, and the elasticity of substitution between capital and labor. A second major source of confusion concerns the mapping from moments into parameters and improper comparisons of empirical results corresponding to different structural objects. In fact, the literature does not even agree on what estimand underlies the Hassett and Hubbard (2002) range, with implications for the effect of taxes on investment that vary by a factor of five or more. A third outstanding problem is the disconnect between empirical estimates of cross-firm short-run investment responses and policy analysis interested in the aggregate long-run response of capital.

The purpose of this article is to reconsider the accumulated evidence relating investment to tax incentives in a theory-consistent manner and to relate the cross-firm empirical evidence to the aggregate response. Section 2 reviews the neoclassical theory of investment of an individual firm i. This firm uses capital and labor to produce output, taking input prices as given. The steady state user cost $R_i = (\rho+\delta)P^K(1-\Gamma_i)/(1-\tau_i)$ consists of the before-tax discount rate and depreciation rate, $\rho+\delta$, multiplied by the price of capital P^K and the "tax term" $(1-\Gamma_i)/(1-\tau_i)$, where τ_i is the firm's marginal tax rate and Γ_i the effective subsidy to the cost of new investment. With a Cobb-Douglas revenue function over capital and labor, $Y_{i,t} = K_{i,t}^{\alpha}L_{i,t}^{\beta}$, Coen (1969) derives the long-run firm-level user cost elasticity inclusive of the feedback from capital to revenue of $-1/(\gamma-1) < -1$, where $\gamma = \alpha/(1-\beta)$. The Coen (1969) elasticity generalizes with any constant elasticity of substitution (CES) over capital and labor, naturally with the elasticity of substitution also mattering. With quadratic adjustment costs in capital, Summers (1981) obtains the relationship $I_{i,t}/K_{i,t} = \delta + (1/\phi)Q_{i,t}$, where $I_{i,t}$ denotes gross investment at date t, $Q_{i,t}$ is a transformation of tax-adjusted Brainard-Tobin's q, and ϕ determines the scale of adjustment costs. Finally, along the linearized transition path following a permanent tax change, the short-run Coen (1969) elasticity scales with the steady state elasticity by the system's stable eigenvalue.

A related but distinct analytical approach derives the optimal capital stock conditional on a firm's sales, similar to Hall and Jorgenson (1967). This tradition of estimating the user cost elasticity holding output fixed dates to Eisner and Nadiri (1968), who pointed out that the Hall and Jorgenson (1967) elasticity of -1 holds only under the Cobb-Douglas production function.

In general, the firm-level user cost elasticity conditional on output is the elasticity of substitution η between capital and labor, since if the firm is a price-taker in input markets the wage remains fixed. While of interest in its own right, applying the phrase "user cost elasticity" to both the Coen (1969) and Eisner and Nadiri (1968) specifications has generated some confusion, for the same reason that Coen (1969) critiqued Hall and Jorgenson (1967).[1]

Section 3 revisits the empirical literature estimating firm or asset-level responses of investment to taxes. The literature has implemented a range of empirical specifications involving possibly minor seeming econometric choices in the dependent variable (I/K or $\log I$ or $\log K$), controls (non-tax component of Brainard-Tobin's q or firm revenue) or timing (short or long-run). Yet, these specifications imply estimands that map into distinct parameters in the neoclassical theory. I provide a Lemma with the mapping for each empirical specification and group them into firm-level estimates of the Summers (1981) specification (Table 1), the Coen (1969) user cost elasticity allowing output to vary (Table 2), hybrid approaches (Table 3), the Eisner and Nadiri (1968) specification holding output fixed (Table 4), and asset-level specifications (Table 5). The majority of estimates are variants of the Coen (1969) specification and map into the short-run semi-elasticity of the investment-to-capital ratio to the user cost, $d\left[I_{i,t}/K_{i,t-1}\right]/d\log R_{i,t}$. The range of values stretches from -0.1 to below -1, with most values in the more compact range of -0.25 to -0.75. This range echoes the Hassett and Hubbard (2002) range of -0.5 to -1. However, my range concerns the semi-elasticity of investment to the user cost and contains adjustments to earlier estimates not made in Hassett and Hubbard (2002).[2]

Section 4 maps the empirical moments into parameter sets. The Summers (1981) and Eisner and Nadiri (1968) specifications translate straightforwardly into the adjustment cost parameter and elasticity of substitution, respectively. The Coen (1969) specifications require more care,

[1] As one example among many, Chirinko, Fazzari and Meyer (1999) directly compare their estimated user cost elasticity from regressing investment on the user cost while controlling for firm revenue to a user cost elasticity they infer from a regression in Cummins, Hassett and Hubbard (1994) that does not control for firm revenue. Dwenger (2014); Council of Economic Advisers (2019); Congressional Budget Office (2018*b*); Council of Economic Advisers (2025); Hartley, Hassett and Rauh (2025) all repeat some version of this error.

[2] Indeed, even the meaning of the Hassett and Hubbard (2002) range remains unsettled. Zwick and Mahon (2017, figure 4) compare the Hassett and Hubbard (2002) range to their coefficient from regressing I/K on the tax term $(1-\Gamma)/(1-\tau)$. Council of Economic Advisers (2019, p.59) interprets the range as applying to the elasticity $d\log I/d\log R$. Since (starting from steady state) $d\left[I_{i,t}/K_{i,0}\right]/d\left[(1-\Gamma_i)/(1-\tau_i)\right] = \left(I_{i,0}/K_{i,0}\right)/\left[(1-\Gamma_i)/(1-\tau_i)\right] \times d\log I_{i,t}/d\log\left[(1-\Gamma_i)/(1-\tau_i)\right] = \delta_i/\left[(1-\Gamma_i)/(1-\tau_i)\right] \times d\log I_{i,t}/d\log R_i$, these objects differ by the ratio of the depreciation rate to the tax term, or roughly a factor of 5 or more. Converting my range to an elasticity would require dividing by I/K, implying much larger values.

since even the transformed regression coefficients are functions of several underlying parameters. Figure 2 contains "trees" that start with different values of the short-run Coen (1969) semi-elasticity, "branch" for different values of the eigenvalue relating the short-to-long-run impulse response and for the elasticity of substitution between capital and labor, and end in "leaves" with the implied values of the revenue elasticity of capital α and adjustment cost parameter ϕ. For an empirical short-run semi-elasticity $d\left[I_{i,t}/K_{i,t-1}\right]/d\log R_{i,t}$ of -0.5, the implied long-run firm-level elasticity of capital to the user cost is around -3 or below. This result highlights the difference between the Coen (1969) elasticity and the elasticity of substitution between capital and labor and associated "neoclassical benchmark" of -1. The values of α range from 0.22 to 0.35, implying total returns to scale in the revenue function of 0.87 or above.

Section 5 discusses how the cross-firm studies inform the effect of changes in tax incentives on aggregate capital, output, wages, and tax revenue. In partial equilibrium, individual firms face flat factor supply curves, taking the wage as fixed. In general equilibrium, factor supply curves may slope up. Under the simplifying assumption that the economy consists of a large number of identical firms, the Coen (1969) elasticity has an analytic general equilibrium counterpart. With Cobb-Douglas, the general equilibrium elasticity of capital to the user cost becomes $-1/(1-\mathcal{M}\alpha)$, where $\mathcal{M} \geq 1$ summarizes the component of decreasing returns in the revenue function due to downward-sloping demand. (For a monopolistically competitive firm it equals the markup.) I refer to this elasticity as the Barro and Furman (2018) elasticity, as these authors use it in their analysis of TCJA. Moving from the Coen (1969) elasticity identified from cross-firm responses to the Barro and Furman (2018) general equilibrium elasticity therefore requires relating α to γ. With CES, the formula again also involves the elasticity of substitution between capital and labor.

Figure 3 summarizes plausible values using trees, now starting from different values of the revenue elasticity of capital α and branching into values of the markup and elasticity of substitution. Under Cobb-Douglas, the long-run general equilibrium elasticity ranges from -1.3 to -1.7. Compared to the firm-level range of -3 or below, this range reflects substantial tightening and general equilibrium dampening due to the aggregate fixed factor of labor. The elasticity of -1.6 used in the actual Barro and Furman (2018) article falls inside it (they set $\alpha = 0.38$ implying $-1/(1-\alpha) = -1.6$), illustrating again the difference between a general equilibrium elasticity and

the "neoclassical benchmark" of -1.

A lower elasticity of substitution η reduces the general equilibrium elasticities of capital and output, as the fixed factor of labor generates faster decreasing returns to capital accumulation. Quantitatively, with constant returns to scale in the firm's revenue function the Barro and Furman (2018) elasticity becomes $-\eta/(1-\mathcal{M}\alpha)$ and hence scales with the elasticity of substitution η. The values of α consistent with the short-run responses of investment imply returns to scale close enough to 1 that this formula roughly holds. The wage elasticity is much less sensitive to the value of η, as a lower elasticity of substitution implies less capital accumulation but faster wage growth per unit of capital. In the constant returns case the wage elasticity becomes $-\mathcal{M}\alpha/(1-\mathcal{M}\alpha)$ and is independent of η; it ranges from -0.3 to -0.7 depending on the values of α, η, and $\mathcal{M}$.

In the U.S. as in many countries, businesses have a choice of corporate form. Figure 4 repeats Figure 3 for an economy with a C-corporate and non-corporate sector and where the user cost change applies only to C-corporations, which in 2022 accounted for 43% of private sector employment. The presence of the non C-corporate sector without a tax change makes the responses of C-corporate capital and output to the C-corporate user cost larger, as the sector can pull in labor. The aggregate response however simply scales with the share of activity in the C-corporate sector.

These results characterize the general equilibrium elasticity of capital to the user cost, $d\log K/d\log R$. The elasticity of aggregate capital to the tax term may be smaller if the non-tax component of the user cost changes, for example because an upward-sloping savings schedule causes higher interest rates ($\rho\uparrow$) or limited capital goods supply increases the price of investment ($P^K\uparrow$). Letting ζ denote the inverse elasticity of the non-tax component to capital, Figure 5 shows that the overall elasticity of capital to the tax term is $(d\log K/d\log R)/(1-\zeta\times(d\log K/d\log R))$.

The final set of analytic results characterizes the tax revenue response in the neoclassical framework. For changes to the corporate rate τ or generosity of expensing z, the change in revenue consists of a mechanical component holding the tax base fixed and a dynamic component as the base changes. Using values for the U.S. in 2024, the dynamic component offsets less than 10% of the mechanical decline when the tax rate falls and between 25% and 45% of the mechanical decline when expensing becomes more generous. Thus, in the relatively low-tax regime in the U.S. in 2024, the neoclassical framework cannot rationalize more than modest dynamic revenue offsets

from further reductions in corporate taxation.

In summary, integrating the empirical evidence into the neoclassical framework delivers the following insights. Empirical estimates of the Coen (1969) specification yield a short-run firm-level semi-elasticity of the investment-to-capital ratio to the user cost in the range of -0.25 to -0.75. The midpoint of this range translates into an elasticity of firm revenue to capital α between 0.22 and 0.35. The reasonableness of these values of α constitutes a victory for the empirical predictions of the neoclassical theory, especially in contrast to early estimates of adjustment costs implied by the Summers (1981) specification. Estimates of the elasticity of substitution between capital and labor η using the Eisner and Nadiri (1968) specification lie in a broad range, including the Cobb-Douglas value of 1 but also lower values. The long-run general equilibrium capital elasticity to the user cost is approximately $-\eta/(1-\mathcal{M}\alpha)$; for $\alpha \subseteq (0.22, 0.34)$ and $\eta \subseteq (0.5, 1)$ it lies between -0.65 and -1.7. The wage elasticity is approximately $-\mathcal{M}\alpha/(1-\mathcal{M}\alpha)$ and lies between -0.3 and -0.7 for economy-wide changes in the user cost or between -0.1 and -0.2 for changes to the user cost in the corporate sector alone. The neoclassical framework cannot rationalize more than modest dynamic revenue offsets from further reductions in corporate taxation in the relatively low-tax regime in the U.S. in 2024.

The analysis concludes by contrasting the neoclassical framework with the practice of leading policy models. Council of Economic Advisers (2019, 2025) follows Hall and Jorgenson (1967) and applies an elasticity of -1 based on the Hassett and Hubbard (2002) range and an appeal to the neoclassical benchmark and then obtains an output response given the higher capital stock, but does not incorporate the additional feedback from output into capital nor the distinction between the corporate and non-corporate sectors. Congressional Research Service (2024) applies an elasticity of -0.6 based on the Eisner and Nadiri (1968) specification and likewise does not incorporate the additional feedback from output into capital. Congressional Budget Office (2018*a*) first applies an Eisner and Nadiri (1968) elasticity of substitution of -0.7 to a user cost change holding output fixed (Congressional Budget Office, 2018*b*) and then allows firm investment to respond to output, essentially marrying the cost-of-capital and investment accelerator approaches but where the feedback from output comes from their macroeconomic model rather than the simpler neoclassical setting.[3]

[3]The critique of policy evaluation and counterfactuals echoes Lucas (1976), who also specifically discussed Hall

2 Theoretical Framework

This section derives key results starting from a firm-level production function. While several of these results can be found elsewhere, to my knowledge they do not exist in one place with common notation and I will refer to them repeatedly in what follows. For ease of reference, Table A.1 summarizes the notation.

Section 2.1 provides the general setup and necessary conditions. Section 2.2 characterizes the steady state and defines the user cost and "tax term". Section 2.3 undergoes cross steady-state analysis with a Cobb-Douglas production function, including deriving the Hall and Jorgenson (1967) specification and the Coen (1969) specification as the limit of a "cobweb" adjustment process in the Hall and Jorgenson (1967) framework. Section 2.4 generalizes to a CES production function and derives the Eisner and Nadiri (1968) elasticity of substitution holding output fixed and the generalized Coen (1969) steady state elasticity. Section 2.5 adds quadratic adjustment costs in capital and derives the Summers (1981) specification. Section 2.6 uses the quadratic adjustment cost environment to relate the cross steady state specifications to their short-run counterparts.

Throughout this section, the analysis concerns a single firm that takes its input prices as given. This partial equilibrium perspective anticipates the firm, asset, or industry-level variation used in the studies reviewed in Section 3. Section 5 extends the results to general equilibrium and shows how the firm-level variation nonetheless disciplines aggregate elasticities.

2.1 General Setup

I set up the problem in continuous time, although nothing essential follows from that choice. More substantively, I ignore uncertainty and assume zero inflation in order to arrive at the key relationships as neatly as possible.

Firm i produces revenue $Y_{i,t}$ using capital $K_{i,t}$ and labor $L_{i,t}$:

$$Y_{i,t} = A_{i,t} F\left(K_{i,t}, L_{i,t}\right), \tag{1}$$

where $A_{i,t}$ denotes exogenous Hicks-neutral technology and $F(.,.)$ is a twice differentiable globally

and Jorgenson (1967). My arguments differ from his however. Lucas (1976) focused on the interpretation of econometric evidence when tax policy is transitory. By contrast, I assume throughout that firms always expect current policy to continue and argue that even this simpler case has not properly integrated economic theory with econometric practice.

concave function.[4] Equation (1) makes no assumption on the structure of demand, only that the function $F(.,.)$ maps capital and labor into revenue. The firm hires labor on the spot market each instant at a common wage W_t. The firm owns its capital stock, a fraction δ of which depreciates each period, giving the law of motion:

$$\dot{K}_{i,t} \equiv dK_{i,t}/dt = I_{i,t} - \delta K_{i,t}, \tag{2}$$

where $I_{i,t}$ denotes gross investment purchased at price P_t^K. Each dollar of investment also requires payment of $\Phi\left(I_{i,t}, K_{i,t}\right)$ dollars of installation costs.

The corporate tax code affects the firm in three ways. First, a firm can deduct from its taxable income a fraction of past investment expenditure. Specifically, for a dollar of investment at date t, the firm can deduct a fraction $B_{i,t}$ immediately and the remainder according to a specified schedule, where $c_{i,t+h|t}$ denotes the fraction of the remainder deductible at horizon h. The fraction $B_{i,t}$ is referred to as "bonus depreciation" or "immediate expensing". Second, the firm may receive an additional investment tax credit $itc_{i,t}$ for investment at date t. The i subscripts in the depreciation schedule and investment tax credit reflect the possibility that they vary by asset type or industry. Third, the corporate income tax $\tau_{i,t}$ applies to revenue net of deductible costs. The i subscript in the tax rate reflects the possibility of credits, deductions, or net operating losses that make the marginal tax rate vary across firms.

The firm's problem simplifies under the maintained assumption that it expects the marginal tax rate to remain fixed.[5] In that case, the present value of tax savings per dollar of investment at date t, denoted $\Gamma_{i,t}$, consists of the investment tax credit plus the tax rate multiplied by the

[4] Allowing for multiple types of capital or labor would complicate some of the expressions below but not change the key results used to interpret empirical work. Likewise, with a constant intermediate inputs share of cost (i.e. Cobb-Douglas over intermediate inputs and factors of production), equation (1) may be reinterpreted as the function giving revenue net of intermediate inputs after concentrating these inputs out of the production function. With fixed costs, K and L in equation (1) should be interpreted as the variable factors of production.

[5] Given an initial capital stock $K_{i,t}$, investment history $\{I_{i,t+h}\}_{h=-\infty}^{0}$, and discount rate ρ, the firm solves: $\max_{\{K_{i,t+h}, I_{i,t+h}, L_{i,t+h}\}_{h=0}^{\infty}} \int e^{-\rho h} CF_{i,t+h} dh$, where cash flows are $CF_{i,t} = (1-\tau_{i,t}) \underbrace{\left(\left(Y_{i,t} - W_t L_{i,t} - \Phi\left(I_{i,t}, K_{i,t}\right)\right)\right)}_{\text{Earnings}} + \tau_{i,t} \underbrace{\left(B_{i,t} P_t^K I_{i,t} + \int_0^\infty \left(1 - B_{i,t-h}\right) c_{i,t|t-h} P_{t-h}^K I_{i,t-h} dh\right)}_{\text{Depreciation allowances}} + \underbrace{itc_{i,t} P_t^K I_{i,t}}_{\text{Tax credit}} - P_t^K I_{i,t}.$
With constant τ, this problem gives the same choices as equation (5).

present value of future depreciation allowances $z_{i,t}$:

$$\Gamma_{i,t} = itc_{i,t} + \tau_{i,t} z_{i,t}, \tag{3}$$

$$\text{where: } z_{i,t} = B_{i,t} + (1 - B_{i,t}) \int_0^\infty e^{-\rho h} c_{i,t+h|t} dh. \tag{4}$$

Furthermore, while accumulated allowances from past investment affect the value of the firm, they do not affect the choice of future investment or capital. The optimal choices of capital and labor therefore arise under the maximization problem:

$$\max_{\{K_{i,t+h}, I_{i,t+h}, L_{i,t+h}\}_{h=0}^\infty} \int e^{-\rho h} \left((1 - \tau_{i,t}) \left(A_{i,t} F\left(K_{i,t}, L_{i,t}\right) - W_t L_{i,t} - \Phi\left(I_{i,t}, K_{i,t}\right) \right) - \left(1 - \Gamma_{i,t}\right) P_t^K I_{i,t} \right), \tag{5}$$

subject to the law-of-motion (2) and the initial conditions.

Let $\lambda_{i,t}$ denote the Lagrange multiplier associated with the constraint (2). Let $F_K\left(K_{i,t}, L_{i,t}\right) = \partial F\left(K_{i,t}, L_{i,t}\right) / \partial K_{i,t}$ and likewise for F_L, Φ_K, Φ_I. The necessary conditions are:

$$L_{i,t}: \qquad A_{i,t} F_L\left(K_{i,t}, L_{i,t}\right) = W_t, \tag{6a}$$

$$K_{i,t}: \qquad \frac{(1 - \tau_{i,t}) \left(A_{i,t} F_K\left(K_{i,t}, L_{i,t}\right) - \Phi_K\left(I_{i,t}, K_{i,t}\right) \right) - \delta \lambda_{i,t} + \dot{\lambda}_{i,t}}{\lambda_{i,t}} = \rho, \tag{6b}$$

$$I_{i,t}: \qquad \left(1 - \tau_{i,t}\right) \Phi_I\left(I_{i,t}, K_{i,t}\right) + \left(1 - \Gamma_{i,t}\right) P_t^K = \lambda_{i,t}. \tag{6c}$$

Equation (6a) states that the firm will always hire labor up to the point where the marginal revenue product equals the wage. Equation (6b) equates the firm's discount rate to the internal rate of return on the shadow value of capital, equal to the after-tax marginal revenue product, less the increment to adjustment costs, and plus the change in the shadow value net of depreciation. Equation (6c) states that the shadow value of capital must equal the cost of investment, given by the sum of the marginal adjustment cost and the market price net of tax incentives.

Equation (6b) solved forward yields:

$$\lambda_{i,t} = \int_t^\infty e^{-(\rho+\delta)h} \left(1 - \tau_{i,t}\right) \left(A_{i,t+h} F_K\left(K_{i,t+h}, L_{i,t+h}\right) - \Phi_K\left(I_{i,t+h}, K_{i,t+h}\right) \right) dh. \tag{7}$$

Thus, the Lagrange multiplier λ equals the present discounted value of an additional unit of capital, where the composite discount rate $\rho + \delta$ accounts for both financial discounting and depreciation and the marginal value at horizon h consists of the after-tax marginal product of capital net of marginal adjustment costs.

2.2 Steady State

Variables without t subscripts denote steady state values. I assume no adjustment costs in steady state, $\Phi(I_i, K_i) = \Phi_I(I_i, K_i) = \Phi_K(I_i, K_i) = 0$. Equation (6c) then gives:

$$\lambda_i = (1 - \Gamma_i) P^K. \tag{8}$$

Substitute this condition into equation (6b) and rearrange slightly:

$$A_i F_K(K_i, L_i) = (\rho + \delta) P^K \left(\frac{1 - \Gamma_i}{1 - \tau_i} \right) \equiv R_i. \tag{9}$$

Equation (9) equates the steady state marginal product of capital to the steady state user cost R_i.[6] The user cost has two terms. The component $(\rho + \delta) P^K$ comprises the opportunity cost and depreciation parts of the cost-of-capital, scaled by the market price. The second component is the "tax term" and will be a key object throughout the analysis. Denote it by $\Omega_{i,t}$:

$$\Omega_{i,t} \equiv \frac{1 - \Gamma_{i,t}}{1 - \tau_{i,t}}. \tag{10}$$

The ratio $\Omega_{i,t}$ summarizes the taxation of capital, with a higher value indicating higher taxation.[7]

Using equation (9), the steady state choices of capital and labor also solve the static maximization problem:

$$\max_{K_i, L_i} A_i F(K_i, L_i) - W L_i - R_i K_i.$$

[6] Away from steady state, one can still define a user cost $R_{i,t}$. However, unlike the steady state R_i, this object contains components not directly measurable in the data such as the marginal increment to adjustment costs. This perspective takes the production function (1) as a technological constraint that holds at every date including outside of steady state. Chirinko (2008) instead views the production function itself as depending on whether the firm has its steady state quantity of capital.

[7] The objective function (5) does not incorporate any deductibility of interest payments. These matter to the firm's first order conditions and hence the user cost insofar as the debt choice depends on the capital stock. With a fixed leverage ratio ψ such that the value of the flow interest deduction is $\tau_i \rho \psi K_i$, the user cost would also subtract $\tau_i / (1 - \tau_i) \rho \psi$. The combination of low tax rates, low interest rates, and modest leverage make interest deductibility less important to capital choice today than historically. For example, Gravelle and Keightley (2025) obtain an average user cost for corporate equipment of 0.184 inclusive of interest deductibility and 0.189 without it (my calculations based on their model and parameters). Nonetheless, accounting for interest deductibility can still non-trivially affect the magnitude of the change in the user cost when τ changes, because τ directly affects the value of the interest deduction. It matters much less for change in the user cost due to changes in z. See Goodman, Isen and Richmond (2025) for an empirical analysis that finds a small effect of interest deductibility on capital.

2.3 Cobb-Douglas Across Steady States

The system (6a) to (6c) simplifies considerably with a Cobb-Douglas production function and across steady states. Thus, specialize equation (1) to:

$$Y_{i,t} = A_{i,t} K_{i,t}^{\alpha} L_{i,t}^{\beta}, \ \alpha > 0, \beta > 0, \alpha + \beta \leq 1. \tag{11}$$

Using $A_i F_K(K_i, L_i) = \alpha Y_i / K_i$ in equation (9) gives the Hall and Jorgenson (1967) relationship:

$$K_i = \frac{\alpha Y_i}{R_i}. \tag{12}$$

Intuitively, under Cobb-Douglas the factor shares of income are constant. With no adjustment costs, the price of capital is the user cost $(\rho + \delta)\Omega_i P^K$. Let lower case letters denote logs of upper case letters, $x \equiv \log X$ (where the lower case letter has an alternative meaning I write instead $\log X$, such as $\log I$ since i indexes individual firms). The Hall and Jorgenson (1967) user cost elasticity associated with equation (12) is:

$$\frac{\partial k_i}{\partial r_i}|_{Y_i = \bar{Y}} = -1. \tag{13}$$

Notably, while this user cost elasticity holds Y_i fixed, in equation (12) Y_i is an endogenous object.

The Coen (1969) elasticity relates K_i to R_i holding fixed only variables exogenous to the firm. To that end, under Cobb-Douglas the first order condition for labor (6a) takes the form:

$$L_{i,t} = \frac{\beta Y_{i,t}}{W_t} = \frac{\beta A_{i,t} K_{i,t}^{\alpha} L_{i,t}^{\beta}}{W_t} = \left(\frac{\beta A_{i,t} K_{i,t}^{\alpha}}{W_t} \right)^{\frac{1}{1-\beta}}. \tag{14}$$

Substitute equation (14) into the Cobb-Douglas production function (11) to find:

$$Y_{i,t} = A_{i,t} K_{i,t}^{\alpha} L_{i,t}^{\beta} = A_{i,t} K_{i,t}^{\alpha} \left(\frac{\beta A_{i,t} K_{i,t}^{\alpha}}{W_t} \right)^{\frac{\beta}{1-\beta}} = \mathcal{A}_{i,t} K_{i,t}^{\gamma}, \tag{15}$$

$$\text{where: } \mathcal{A}_{i,t} \equiv \left(\beta^{\beta} A_{i,t} W_t^{-\beta} \right)^{\frac{1}{1-\beta}}, \tag{16}$$

$$\gamma \equiv \frac{\alpha}{1-\beta} \subset (0, 1). \tag{17}$$

Importantly, $\mathcal{A}_i$ contains only variables exogenous to the firm. The Coen (1969) user cost elasticity follows from applying the chain rule using equation (15) to equation (12):

$$\frac{dk_i}{dr_i} = -1 + \frac{\partial y_i}{\partial k_i} \times \frac{dk_i}{dr_i} = -\frac{1}{1-\gamma} \leq -1. \tag{18}$$

This elasticity captures the full firm-level response of capital, taking the wage as exogenous. Furthermore, since in the steady state $I_i = \delta K_i$, equation (18) also gives the long-run elasticity of gross investment:

$$\frac{d \log I_i}{dr_i} = \frac{dk_i}{dr_i} = -\frac{1}{1-\gamma} \leq -1. \tag{19}$$

The feature that the Coen (1969) firm-level elasticity with Cobb Douglas is always weakly less than -1 clearly distinguishes it from the Hall and Jorgenson (1967) "neoclassical benchmark". The inequality is strict as long as $\alpha > 0$.

It is instructive to arrive at equation (18) by instead starting from equation (12) and iterating in a cobweb adjustment process. Thus, suppose a firm starts with capital $K_{i,0}$ and output $Y_{i,0}$ satisfying equations (12) and (15), implying $K_{i,0} = (\alpha \mathcal{A}_{i,0}/R_i)^{1/(1-\gamma)}$. At date 0, the log user cost r_i falls by an amount Δ. To ease exposition, temporarily let $\mathcal{A}_{i,t} = 1 \ \forall t$. If the firm uses the static updating rule given by equation (12) and changes its capital stock only periodically at dates $t = 1, 2, ...$, its capital and output will evolve over time as:

Horizon	$k_{i,t}$	$y_{i,t}$
0	$k_{i,0}$	$\gamma k_{i,0}$
1	$\log \alpha + \gamma k_{i,0} - (r_i - \Delta)$	$\gamma k_{i,1}$
2	$\log \alpha + \gamma \left(\log \alpha + \gamma k_{i,0} - (r_i - \Delta) \right) - (r_i - \Delta)$	$\gamma k_{i,2}$
$\vdots$		
$t > 0$	$\gamma^t k_{i,0} + \sum_{h=1}^{t} \gamma^{h-1} \left(\log \alpha - (r_i - \Delta) \right)$	$\gamma k_{i,t}$

The cobweb adjustment process sheds additional light on the Coen (1969) critique of Hall and Jorgenson (1967). Hall and Jorgenson analyzed tax reforms by applying only step 1 of the iterative process, yielding the elasticity -1. Coen correctly noted that iterating fully would yield the elasticity $-\lim_{t \to \infty} \sum_{h=1}^{t} \gamma^{h-1} = -1/(1-\gamma)$. Hall and Jorgenson (1969, p.369) replied that with constant returns to scale in the revenue function, $\alpha + \beta = 1$, the parameter γ also equals 1 and the full firm-level elasticity becomes infinite, implying "serious shortcomings" of the Coen approach. While the statement that constant returns implies an infinite elasticity is true, an alternative perspective is that the coexistence of firms facing different user costs sheds light on the

degree of returns to scale at the firm level. Furthermore, and as discussed in detail in Section 5, this issue disappears for aggregate analysis since aggregate labor is not infinitely elastic.

2.4 Constant Elasticity of Substitution (CES) Across Steady States

The Hall and Jorgenson (1967) and Coen (1969) elasticities generalize under more general CES production. Thus, now define $F\left(K_{i,t}, L_{i,t}\right)$ in equation (1) as:

$$F\left(K_{i,t}, L_{i,t}\right) = \left(\left(\frac{\alpha}{\alpha+\beta}\right) K_{i,t}^{1-1/\eta} + \left(\frac{\beta}{\alpha+\beta}\right) L_{i,t}^{1-1/\eta}\right)^{\frac{(\alpha+\beta)\eta}{\eta-1}}, \ \alpha>0, \beta>0, \eta>0, \alpha+\beta\leq 1. \tag{20}$$

Here $\alpha+\beta$ still determines the returns to scale in the revenue function, while η is the elasticity of substitution between capital and labor. Using $\frac{(\alpha+\beta)\eta}{\eta-1} - 1 = \frac{(\alpha+\beta)\eta}{\eta-1}\left(1 + \frac{1-\eta}{(\alpha+\beta)\eta}\right)$, the derivatives of this function are:

$$F_K\left(K_{i,t}, L_{i,t}\right) = \alpha F\left(K_{i,t}, L_{i,t}\right)^{1+\frac{1-\eta}{(\alpha+\beta)\eta}} K_{i,t}^{-\frac{1}{\eta}}, \tag{21a}$$

$$F_L\left(K_{i,t}, L_{i,t}\right) = \beta F\left(K_{i,t}, L_{i,t}\right)^{1+\frac{1-\eta}{(\alpha+\beta)\eta}} L_{i,t}^{-\frac{1}{\eta}}. \tag{21b}$$

Substitute equation (21a) into equation (9) relating the marginal product of capital to the user cost to obtain (see e.g. Eisner and Nadiri, 1968):

$$A_i \alpha \left(Y_i/A_i\right)^{1+\frac{1-\eta}{(\alpha+\beta)\eta}} K_i^{-\frac{1}{\eta}} = R_i. \tag{22}$$

The generalized Hall and Jorgenson (1967) user cost elasticity associated with equation (22) is:

$$\frac{\partial k_i}{\partial r_i}|_{Y_i=\bar{Y}} = -\eta. \tag{23}$$

Next solve for the Coen (1969) specification. Define $\alpha_i^* \equiv R_i K_i/Y_i$ and $\beta_i^* \equiv W_i L_i/Y_i$ as the steady state revenue shares of capital and labor, respectively. Take logs and implicitly differentiate equation (22) with respect to r_i and rearrange:

$$\frac{dk_i}{dr_i} = \left(\left(1 + \frac{1-\eta}{(\alpha+\beta)\,\eta}\right)\frac{\partial y_i}{\partial k_i} - \frac{1}{\eta}\right)^{-1}. \tag{24}$$

Substitute equation (21b) into equation (6a) with the wage fixed (to derive the partial equilibrium firm-level elasticity), take logs and differentiate to obtain $\partial y_i/\partial k_i$ (see equation (A.2)), and

substitute this expression into equation (24) to find the generalized Coen (1969) elasticity (see equation (A.3)):[8]

$$\frac{dk_i}{dr_i} = -\left(\frac{1-\beta_i^*\left(\eta+\frac{1-\eta}{\alpha+\beta}\right)}{1-\alpha-\beta}\right). \tag{25}$$

With $\eta = 1$, equation (25) simplifies to $-(1-\beta)/(1-\alpha-\beta) = -1/(1-\gamma)$ as in equation (18). Away from $\eta = 1$, the degree of returns to scale in the revenue function governs how far equation (25) differs from equation (18). As $\alpha+\beta \to 1$ (constant returns to scale), η ceases to matter and the Coen (1969) elasticity diverges to negative infinity.

2.5 Adjustment Costs

Summers (1981) and Hayashi (1982) analyze quadratic adjustment costs in capital. The subsequent literature has emphasized more complicated adjustment costs including over investment rather than capital (Christiano, Eichenbaum and Evans, 2005) or fixed or irreversible costs of adjustment (Abel and Eberly, 1994, 1996; Caballero and Engel, 1999; Caballero, 1999; Cooper and Haltiwanger, 2006; Winberry, 2021). Without disputing the importance of these features, the motivation for this article is that the empirical literature has sometimes erred in relating moments to parameters even in the most "vanilla" setting.

The quadratic adjustment costs take the form:

$$\Phi\left(I_{i,t}, K_{i,t}\right) = \frac{\phi}{2}\left(\frac{I_{i,t}}{K_{i,t}} - \delta\right)^2 K_{i,t}, \tag{26}$$

$$\text{with: } \Phi_I\left(I_{i,t}, K_{i,t}\right) = \phi\left(I_{i,t}/K_{i,t} - \delta\right),$$

$$\Phi_K\left(I_{i,t}, K_{i,t}\right) = \Phi\left(I_{i,t}, K_{i,t}\right)/K_{i,t} - \left(I_{i,t}/K_{i,t}\right)\Phi_I\left(I_{i,t}, K_{i,t}\right).$$

Substituting the expression for $\Phi_I\left(I_{i,t}, K_{i,t}\right)$ into the investment necessary condition (6c) yields the Summers (1981) equation:

$$\frac{I_{i,t}}{K_{i,t}} = \delta + \frac{1}{\phi}Q_{i,t}, \tag{27}$$

$$\text{where: } Q_{i,t} \equiv \frac{\lambda_{i,t} - P_t^K\left(1-\Gamma_{i,t}\right)}{1-\tau_{i,t}} = \frac{\lambda_{i,t}}{1-\tau_{i,t}} - P_t^K\Omega_{i,t}. \tag{28}$$

[8] The derivation also uses the result that the sum of revenue shares equals the returns to scale of the revenue function, $\alpha_i^* + \beta_i^* = \alpha + \beta$ (see equation (A.1)).

The recognition of the difference between the market value of an additional unit of capital, $\lambda_{i,t}$ (see equation (7)), and the tax-adjusted replacement cost, $P_t^K(1-\Gamma_{i,t})$, as a determinant of investment dates to Brainard and Tobin (1968). The ratio of these values is referred to as Brainard-Tobin's q. The definition of Q in equation (28) is a transformation of this concept.

2.6 Coen (1969) in the Short-run

The linearized dynamic transition path links the cross steady state firm-level results to short-run empirical specifications. To that end, define the mapping from capital to revenue net of labor costs:

$$G_{i,t}(K_{i,t}) \equiv \max_{L_{i,t}} A_{i,t}F(K_{i,t}, L_{i,t}) - W_t L_{i,t}, \tag{29}$$

where $G_{i,t}(K_{i,t})$ has concentrated out labor using the first order condition (6a). Under Cobb-Douglas $G_{i,t}(K_{i,t}) = (1-\beta)\mathcal{A}_{i,t}K_{i,t}^{\gamma}$ (see equation (15)); more generally the i,t subscripts on the G function reflect the dependence on technology and the wage. Importantly, $G_{i,t}(K_{i,t})$ inherits the concavity of equation (1), with in particular $G'_{i,t}(K_{i,t}) = A_{i,t}F_K(K_{i,t}, L_{i,t})$.[9]

Imposing quadratic adjustment costs, the system (6b) and (6c) takes the form:

$$\dot{\lambda}_{i,t} = (\rho+\delta)\lambda_{i,t} - (1-\tau_{i,t})\left(G'_{i,t}(K_{i,t}) - \Phi_K(I_{i,t}, K_{i,t})\right), \tag{30a}$$

$$\dot{K}_{i,t} = \frac{1}{\phi}\left(\frac{\lambda_{i,t} - (1-\Gamma_{i,t})P_t^K}{1-\tau_{i,t}}\right)K_{i,t}. \tag{30b}$$

Take a Taylor expansion in the neighborhood of the steady state (see Appendix A.2 for details):

$$\begin{pmatrix}\dot{\lambda}_{i,t}\\ \dot{K}_{i,t}\end{pmatrix} = \begin{pmatrix}\rho & -(1-\tau_i)G''_i(K_i)\\ K_i/(\phi(1-\tau_i)) & 0\end{pmatrix}\begin{pmatrix}\lambda_{i,t}-\lambda_i\\ K_{i,t}-K_i\end{pmatrix}. \tag{31}$$

Consider a permanent tax change at date 0 that, in keeping with this section's partial equilibrium perspective, affects only firm i.[10] Using the approximation $k_{i,t} - k_i \approx (K_{i,t}-K_i)/K_i$, for an

[9] Using equation (6a) and defining $H_{i,t}(K_{i,t}) = L_{i,t}$ as the mapping from capital to labor, $G'_{i,t}(K_{i,t}) = A_{i,t}F_K(K_{i,t}, L_{i,t}) + (A_{i,t}F_L(K_{i,t}, L_{i,t}) - W_t)H'_{i,t}(K_{i,t}) = A_{i,t}F_K(K_{i,t}, L_{i,t})$, and $G''_{i,t}(K_{i,t}) = A_{i,t}\left(F_{KK}(K_{i,t}, L_{i,t}) + F_{LL}(K_{i,t}, L_{i,t})H'_{i,t}(K_{i,t})^2 + 2F_{KL}(K_{i,t}, L_{i,t})H'_{i,t}(K_{i,t})\right)$.

[10] A reform affecting all firms would involve changes in aggregate variables such as the wage. These changes would appear as additional forcing terms in equations (32a) and (32b) and contribute to the regression intercept in the Coen (1969) specifications reviewed in Section 3.

initial condition $k_{i,0}$, the solution is:

$$\lambda_{i,t} - \lambda_i = \phi\left(1 - \tau_i\right)\left(k_{i,0} - k_i\right)\chi e^{\chi_i t}, \tag{32a}$$

$$k_{i,t} - k_i = \left(k_{i,0} - k_i\right)e^{\chi_i t}, \tag{32b}$$

$$\text{where: } \chi_i \equiv \frac{\rho}{2} - \sqrt{\left(\frac{\rho}{2}\right)^2 - \frac{G_i''\left(K_i\right)K_i}{\phi}} < 0 \tag{33}$$

is the stable eigenvalue of the system.[11] Implicitly differentiate the capital first order condition $G_{i,t}'\left(K_{i,t}\right) = A_{i,t}F_K\left(K_{i,t}, L_{i,t}\right) = R_i$ with respect to R_i at the steady state and rearrange to find:

$$1 = \frac{G_i''\left(K_i\right)K_i}{R} \times \frac{dk_i}{dr_i}.$$

Substitute into equation (33):

$$\chi_i = \frac{\rho}{2} - \sqrt{\left(\frac{\rho}{2}\right)^2 - \left(\frac{dk_i}{dr_i}\right)^{-1}\frac{R_i}{\phi}} < 0, \tag{34}$$

where dk_i/dr_i is the Coen (1969) elasticity in (18) or (25).

We can now state the key short-run results. The derivative of $k_{i,t}$ with respect to r_i in equation (32b) gives the elasticity of capital along the transition path:

$$\frac{dk_{i,t}}{dr_i} = \left(1 - e^{\chi_i t}\right)\frac{dk_i}{dr_i}. \tag{35}$$

The response of log net investment $\dot{k}_{i,t}$ is given by the time derivative of equation (32b):

$$\dot{k}_{i,t} = \frac{\dot{K}_{i,t}}{K_{i,t}} = \frac{I_{i,t}}{K_{i,t}} - \delta = \chi_i\left(k_{i,0} - k_i\right)e^{\chi_i t}. \tag{36}$$

The semi-elasticity of $I_{i,0}/K_{i,0}$ to the user cost after t periods is therefore:

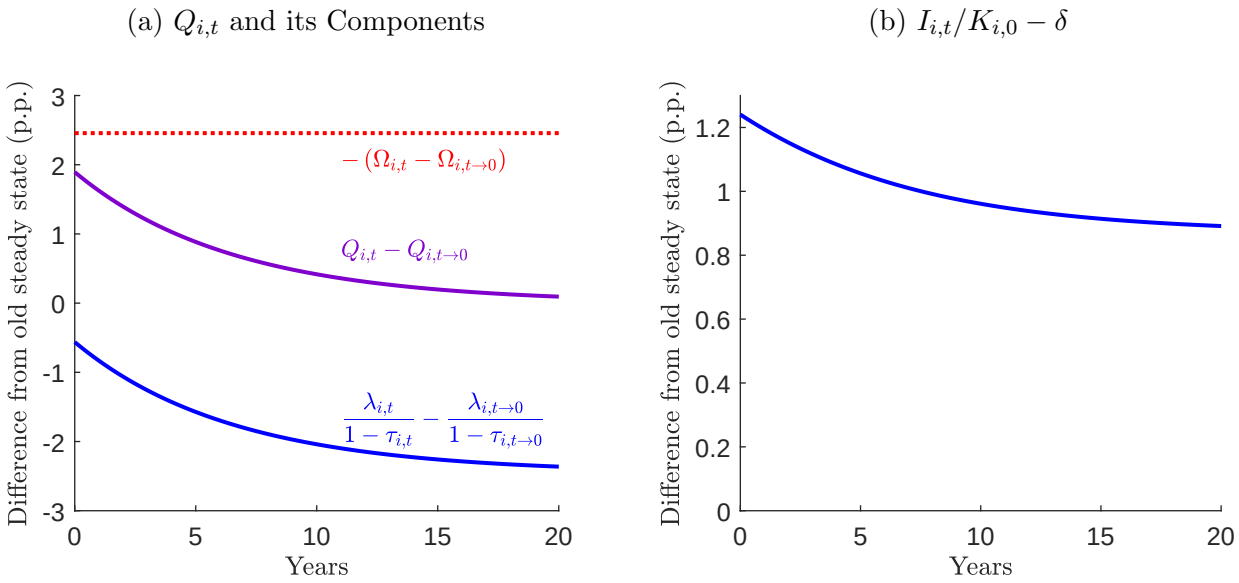
$$\frac{dI_{i,t}/K_{i,t}}{dr_i} = -\chi_i e^{\chi_i t}\frac{dk_i}{dr_i}. \tag{37}$$

In particular, the short-run semi-elasticity is $-\chi_i dk_i/dr_i$.

The result that the eigenvalue χ_i scales the short-run response of the investment rate to the long-run elasticity of capital depends on the assumption of convex adjustment costs. Section 4

[11] Auerbach (1989) first derives the partial adjustment form of the transition path as in equation (32b). The formula (34) differs slightly from Auerbach's due to my assumption that adjustment costs are fully immediately depreciable from income. Auerbach (1989) and Auerbach and Hassett (1992) also allow for transitory tax policy changes, in which case k_i depends on both current and future tax policy.

Figure 1: Impulse Response of Q and I/K



Notes: In Panel (a), the dotted red line shows the absolute value of the change in the tax term Ω, the solid blue line shows the response of the market value of installed capital $\lambda/(1-\tau)$, and the solid purple line shows the response of Q. Panel (b) shows the percentage point increase in the investment-capital ratio I/K.

will use this fact and the definition (34) to recover ϕ given other parameters. It merits mention that with more complicated adjustment costs one can still characterize the shape of the impulse response function and relate the short-run and long-run elasticities, although not necessarily as a closed form function of parameters (Chodorow-Reich et al., 2025).

The statement that a finite firm-level elasticity implies diminishing returns to scale in revenue does not carry over to the short-run elasticity. Take the Cobb-Douglas case for simplicity, in which $dk_i/dr_i = -1/(1-\gamma)$ (equation (18)). Apply L'Hopital's rule to $\chi_i/(1-\gamma)$ (see equation (37)):

$$\lim_{\gamma\to 1} \frac{dI_{i,0}/K_{i,0}}{dr_i} = \lim_{\gamma\to 1} \frac{\chi_i}{1-\gamma} = -\frac{R_i}{\rho\phi}. \tag{38}$$

In the knife edge case of constant returns to scale, the short-run semi-elasticity contains no information about the long-run elasticity. The exact functional form of the limit depends on the functional form of adjustment costs.

Figure 1 plots the transition path of the components of $Q_{i,t}$ and $I_{i,t}/K_{i,0}$ in response to a change in $\Omega_{i,t}$ due to more generous expensing. The top dotted line in Figure 1(a) shows the absolute value of the change in Ω, which in this example falls by 2.5p.p., roughly the difference between 0 and 100% expensing of equipment at the current marginal tax rate and depreciation schedule (Chodorow-Reich et al., 2025). The remainder of the calibration is illustrative but realistic: the

production function is Cobb-Douglas with $\alpha = 0.25, \beta = 0.65$, a depreciation rate $\delta = 0.1$, a discount rate $\rho = 0.06$, and adjustment cost parameter $\phi = 1.5$. The middle line shows that $Q_{i,t}$ jumps up at date 0, but by less than the reduction in $\Omega_{i,t}$. Arithmetically, $\lambda_{i,t}$ must then jump down, as shown in the bottom line. Figure 1(b) shows that investment jumps above the new long run steady state value and converges toward it from above.[12] In this example the log change in $\Omega_{i,t}$ is -2.4% and $\gamma = 5/7$, implying a long-run increase in investment of $2.4\%/(1-\gamma) = 8.4\%$ (see equation (18)), or a level change of 0.84p.p. of initial capital given $\delta = 0.1$. Furthermore, $\chi_i \approx -0.15$, giving $I_{i,0}/K_{i,0} - \delta = -\chi_i \times 8.4\% = 1.24\%$ of K_0 (see equation (37)), equal to the date 0 value of the impulse response shown in Figure 1(b).

3 A Reanalysis of Empirical Findings

This section reviews empirical estimates of the effect of taxes on capital and investment across firms or asset types. Section 3.1 considers the Summers (1981) specification and relates empirical estimates to the adjustment cost parameter ϕ. Section 3.2 reports variants of the Coen (1969) specification and relates empirical estimates to the long-run capital elasticity dk_i/dr_i and the short-run scalar given by the eigenvalue χ_i. Section 3.3 reviews hybrid specifications. Section 3.4 considers variants of the Eisner and Nadiri (1968) specification and relates empirical estimates to the elasticity of substitution η. Section 3.5 reports asset-level specifications. Section 4 further relates the Coen (1969) specifications to primitive parameters, sometimes with the use of auxiliary information. As all of the regression specifications apply to individual units or asset types, they omit the effect of common changes to aggregate factor prices. Section 5 addresses this "missing intercept" problem and characterizes aggregate elasticities.

The set of papers builds on Zwick and Mahon (2017, table B.8). I restrict analysis to firm or asset-level studies relating investment to changes in corporate tax policy. Bond and Van Reenen (2007) review estimates of investment-related parameters using other sources of variation or structural methods. To keep the analysis manageable, with one exception I also restrict to results using U.S. data.[13] I do not devote space to critiquing research designs. Most share the approach of using

[12] This qualitative pattern is not generic; with ϕ large enough $\lambda_{i,t}$ can jump up and investment can converge to its long-run value from below.

[13] Recent articles using non-U.S. data include Maffini, Xing and Devereux (2019); Guceri and Albinowski (2021); Harju, Koivisto and Matikka (2022); Link et al. (2024); Lerche (2025).

changes in tax law that have heterogeneous effects across industries or firms. Hence, they rely on the units most exposed to the changes in taxes not also being differentially exposed to other common shocks. My interpretation of the cross-sectional results further assumes that tax changes specific to an individual firm or asset type do not cause firm or asset-specific changes in input prices, as such changes would contribute to the regression residuals.[14]

For readers less interested in the details of individual studies, each sub-section concludes with a paragraph summarizing the evidence.

3.1 Estimates of the Summers (1981) Specification

Because it explicitly applies at short horizons, a straightforward specification is the Summers (1981) equation:

$$I_{i,t}/K_{i,t-1} = b_0^{I/K,Q} + b_1^{I/K,Q} Q_{i,t}, \tag{39}$$

where $Q_{i,t}$ is defined in equation (28). Lemma 1 formalizes the interpretation of $b_1^{I/K,Q}$ using equation (27):

Lemma 1 *In the environment of Section 2.5 with quadratic adjustment costs in capital, plim* $b_1^{I/K,Q} = 1/\phi$*, where* ϕ *scales the adjustment cost in equation* (26)*.*

Table 1 reviews empirical estimates.

Summary. The implied values of ϕ of roughly 50 found in Cummins, Hassett and Hubbard (1994) and Desai and Goolsbee (2004) seem implausibly high; they suggest that a firm could pay more than \$1 of adjustment costs per dollar of new capital.[15] The literature has interpreted the small coefficients shown in Table 1 (and earlier in Summers (1981) in the time series) as reflecting attenuation bias stemming from measurement error in the λ component of Q, including the difficulty of measuring the marginal rather than average value of a unit of capital. Cummins, Hassett

[14] See House and Shapiro (2008) for a joint analysis of investment and its price in response to bonus depreciation. Because their setup assumes a temporary tax change, I do not include it among the studies reviewed below, acknowledging here that whether the onset of bonus depreciation in 2001 was viewed as transitory or permanent policy matters to the interpretation of analyses of that episode. In general, better measurement of firms' expectations of the persistence of tax policy would be an important step forward in refining the user cost changes during particular episodes and hence in comparing across some of the studies reviewed below.

[15] An additional failure of estimation of equation (39) concerns the absence of a theoretical rationale for a regression residual, suggesting the R^2 should be one.

Table 1: Estimates of the Summers (1981) Specification

Article	Table (col.)	Estimating equation	Data	Variation	b_1 (s.e.)	Implied ϕ
Cummins, Hassett and Hubbard (1994)	3(2)	$I_{i,t}/K_{i,t-1} = b_0 + b_1 Q_{i,t}$	Compustat annual 1953-1988	Firm-level with year and firm FE and control for cash flow (het. SEs)	$b_1 =$ 0.019 (0.001)	52.6
Cummins, Hassett and Hubbard (1996)	7	$I_{i,t}/K_{i,t-1} = b_0 + b_1 Q_{i,t}$	Global Vantage USA 1987	Firm-level first-differences IV using $\Omega_{i,t}$ and lagged $I_{i,t}/K_{i,t-1}$ and cash flow (het. SEs)	$b_1 =$ 0.650 (0.077)	1.5
Desai and Goolsbee (2004)	7(2)	$I_{i,t}/K_{i,t-1} = b_0 + b_1 Q_{i,t}$	Compustat annual 1962-2003	Four-digit SIC with year and firm FE (cluster by firm) and control for cash flow	$b_1 =$ 0.0231 (0.0011)	43.3

and Hubbard (1996) use tax variation as an excluded instrument to address the measurement error and find a much larger regression coefficient and implied value of ϕ of 1.5.[16]

3.2 Estimates of the Coen (1969) Specification

Table 2 reviews articles that estimate variants of the equations:

$$k_{i,t} = b_0^{\text{Coen}k,r} + b_1^{\text{Coen}k,r} \log \Omega_{i,t} + e_{i,t}, \tag{40a}$$

$$\log I_{i,t} = b_0^{\text{Coen}\log I,r} + b_1^{\text{Coen}\log I,r} \log \Omega_{i,t} + e_{i,t}, \tag{40b}$$

$$I_{i,t}/K_{i,t-1} = b_0^{\text{Coen}I/K,r} + b_1^{\text{Coen}I/K,r} \log \Omega_{i,t} + e_{i,t}, \tag{40c}$$

$$I_{i,t}/K_{i,t-1} = b_0^{\text{Coen}I/K,\Omega} + b_1^{\text{Coen}I/K,\Omega} \Omega_{i,t} + e_{i,t}, \tag{40d}$$

$$I_{i,t}/K_{i,t-1} = b_0^{\text{Coen}I/K,R} + b_1^{\text{Coen}I/K,R} R_{i,t} + e_{i,t}, \tag{40e}$$

$$\log I_{i,t} = b_0^{\text{Coen}\log I,z} + b_1^{\text{Coen}\log I,z} z_{i,t} + e_{i,t}. \tag{40f}$$

Specifications (40a) to (40f) all relate firm capital or investment to the tax term $\Omega_{i,t}$, user cost $R_{i,t}$, or depreciation allowances $z_{i,t}$, as defined in equations (4), (9) and (10). They are estimated in differences, with firm fixed effects, or by first purging the left and right hand sides of date $t-1$ expectations.[17]

[16] Technically, their excluded instrument is the variable $\tilde{Q}_{i,t}$ defined in equation (41). As discussed there, the identifying variation is simply the tax term $\Omega_{i,t}$.

[17] One can formally define the regression residuals in equations (40a) to (40f) as functions of changes to idiosyncratic productivity or components of the user cost besides the tax term, such as capital goods prices. If b_1 is heterogeneous, the Lemmas also require that the heterogeneity be uncorrelated with the regressor.

Lemmas 2 to 5 map these specifications into the long-run Coen (1969) elasticity dk_i/dr_i or its short or medium-run counterpart also involving the eigenvalue χ_i. Equation (40a) across steady states directly mirrors equations (18) and (25):

Lemma 2 *In the environment of Section 2.3 with Cobb-Douglas production across steady states, plim* $b_1^{Coenk,r} = dk_i/dr_i = -1/(1-\gamma)$*, where* $\gamma = \alpha/(1-\beta)$ *as in equation (17). In the general CES case, plim* $b_1^{Coenk,r} = dk_i/dr_i = -\left(\frac{1-\beta_i^*\left(\eta+\frac{1-\eta}{\alpha+\beta}\right)}{1-\alpha-\beta}\right)$.

Lemma 2 also applies to equation (40b) estimated across steady states, since $d\log I_i = dk_i$. The long-run elasticity *plim* $b_1^{\text{Coen}k,r} = dk_i/dr_i$ will appear throughout the remainder and I will usually drop the *plim* for compactness.

Equations (40a) to (40f) are also frequently estimated at shorter horizons. Let $k(h)$ and $I(h)$ denote log capital and investment h periods after a tax change; for compactness, continue to use the shorthand $k = k(\infty)$ when no explicit argument for h is given. Using equations (35) and (37):

Lemma 3 *In the environment of Section 2.6 with quadratic adjustment costs in capital, equation (40a) estimated h periods after a tax reform recovers plim* $b_1^{Coenk(h),r} = \left(1-e^{\chi_i h}\right) b_1^{Coenk,r}$*, where* χ_i *is the stable eigenvalue given in equation (34). Using* $dI_{i,0}/K_{i,0} = \delta d\log I_{i,0}$*, equation (40b) estimated immediately after a tax reform recovers plim* $b_1^{Coen\log I(0),r} = -\left(\chi_i/\delta\right) b_1^{Coenk,r}$ *and equation (40c) recovers plim* $b_1^{CoenI(0)/K,r} = -\chi_i b_1^{Coenk,r}$.

Equations (40d) to (40f) require additional steps since their regressors are $\Omega_{i,t}, R_{i,t}$, or $z_{i,t}$, respectively, rather than $\log\Omega_{i,t}$ as in equations (40a) to (40c). Equation (40d) appears close to the Summers specification (39); both specifications have $I_{i,t}/K_{i,t-1}$ on the left hand side and they differ only in whether the regressor includes the component $\lambda_{i,t}/(1-\tau_{i,t})$ in $Q_{i,t}$. From the perspective of equation (39), this difference has an interpretation of omitted variables bias in equation (40d), since the tax change also causes a change in $\lambda_{i,t}$, as shown in Figure 1. The correct interpretation of equation (40d) therefore comes from equation (37) after rescaling the regression coefficient by $\Omega_{i,t}$, since equation (37) and Lemma 3 relate $I_{i,t}/K_{i,t}$ to the log rather than the level of the tax term. A similar interpretation applies to equation (40e):

Lemma 4 *In the environment of Section 2.6 with quadratic adjustment costs in capital, equation (40d) estimated immediately after a tax reform recovers plim* $b_1^{CoenI(0)/K,\Omega} = (1/\Omega_i) plim\, b_1^{CoenI(0)/K,r} =$

$-(\chi_i/\Omega_i)\, b_1^{Coenk,r}$ *and equation* (40e) *recovers plim* $b_1^{CoenI(0)/K,R} = (1/R_i) plim\ b_1^{CoenI(0)/K,r} = -(\chi_i/R_i)\, b_1^{Coenk,r}$. *Equation* (40e) *estimated* h *periods after a tax reform recovers plim* $b_1^{CoenI(h)/K(h),R} = -(\chi_i/R_i) e^{\chi_i h} b_1^{Coenk,r}$.

Finally for equation (40f):

Lemma 5 *Assume the environment of Section 2.6 with quadratic adjustment costs in capital. Using* $dz = \left(\frac{1-\Gamma}{\tau}\right) \frac{d\tau z}{1-\Gamma} = -\left(\frac{1-\Gamma}{\tau}\right) d\log(1-\Gamma)$, *plim* $b_1^{Coen \log I(0),z} = (\chi_i/\delta)\,(\tau/(1-\Gamma))\, b_1^{Coenk,r}$; *also using Lemma 3, plim* $b_1^{Coenk(h),z} = -(\tau/(1-\Gamma))\left(1 - e^{\chi_i h}\right) b_1^{Coenk,r}$.

Table 2 reports estimates of variants of equations (40a) to (40f) as well as my best attempt to standardize and compare the regression coefficients. As described in Lemmas 2 to 5, this process involves up to two steps. Step one applies standard manipulations such as multiplying or dividing by the sample mean of the regressor to transform investment coefficients estimated h periods after a tax change into the semi-elasticity $b_1^{\text{Coen}I(h)/K,r}$ and capital coefficients into the elasticity $b_1^{\text{Coen}k(h),r}$. Step two relates these objects to the long-run Coen (1969) elasticity $b_1^{\text{Coen}k,r} = dk_i/dr_i$ and the eigenvalue χ.

The setup in Cummins, Hassett and Hubbard (1994, table 5) requires additional commentary. Cummins, Hassett and Hubbard (1994) is a landmark, comprehensive analysis of firm-level investment around major U.S. tax reforms and is among the most prominently-cited articles in the literature and for policy analysis. They motivate their first main specification (equations (10)-(11) in their paper with results shown in their table 5) as a variant of the Summers (1981) specification in (39), but setting the regressor to $\tilde{Q}_{i,t} - \mathbb{E}_{i,t-1}\tilde{Q}_{i,t}$, where:

$$\tilde{Q}_{i,t} = \frac{\lambda_{i,t-2} - P^K_{i,t-2}\,(1-\Gamma_{i,t})}{1-\tau_{i,t}}, \tag{41}$$

and $\mathbb{E}_{i,t-1}$ is an expectation operator implemented by projecting on lags of investment, cash flow, and a time trend. The purging of lagged information using $\mathbb{E}_{i,t-1}$ is innocuous (it isolates the shock). The definition of $\tilde{Q}_{i,t}$ as including $\lambda_{i,t-2}$, however, instead of $\lambda_{i,t}$ as in equation (28), changes the interpretation of their regression in a manner unrecognized at the time or since. Cummins, Hassett and Hubbard (1994, p.30) describe this substitution as intended to "focus on the tax surprise" given the possibility of measurement error in the λ component. Yet, this substitution also removes the endogenous response of $\lambda_{i,t}$ to tax changes. Furthermore, the purging of lagged

Table 2: Estimates of the Coen (1969) Specification

Article	Table (col.)	Estimating equation	Data	Variation	b (s.e.)	Transformation
Cummins, Hassett and Hubbard (1994) major reforms	5	$I_{i,t}/K_{i,t-1} = b_0 + b_1\tilde{Q}_{i,t}$	Compustat annual	Firm-level projecting out expectations (het. SEs)		$b \times \Omega$ (Lemma 4), lagged Ω from table 1 and figure 1
			1963		0.874 (0.23)	$\Omega = 1.35 : -b_1^{\text{Coen}I(0)/K,r} = \chi b_1^{\text{Coen}k,r} = 1.18$
			1973		0.47 (0.095)	$\Omega = 1.30 : -b_1^{\text{Coen}I(0)/K,r} = \chi b_1^{\text{Coen}k,r} = 0.61$
			1982		0.599 (0.10)	$\Omega = 1.11 : -b_1^{\text{Coen}I(0)/K,r} = \chi b_1^{\text{Coen}k,r} = 0.66$
			1987		0.613 (0.09)	$\Omega = 1.31 : -b_1^{\text{Coen}I(0)/K,r} = \chi b_1^{\text{Coen}k,r} = 0.80$
Cummins, Hassett and Hubbard (1994) major reforms	9	$I_{i,t}/K_{i,t-1} = b_0 + b_1 R_{i,t}$	Compustat annual equipment	Firm-level projecting out expectations (het. SEs)		$-b \times R$ (Lemma 4), $R = 0.25$ (p. 43):
			1963		-0.605 (0.14)	$-b_1^{\text{Coen}I(0)/K,r} = \chi b_1^{\text{Coen}k,r} = 0.15$
			1973		-0.546 (0.14)	$-b_1^{\text{Coen}I(0)/K,r} = \chi b_1^{\text{Coen}k,r} = 0.14$
			1982		-0.757 (0.19)	$-b_1^{\text{Coen}I(0)/K,r} = \chi b_1^{\text{Coen}k,r} = 0.19$
			1987		-0.747 (0.23)	$-b_1^{\text{Coen}I(0)/K,r} = \chi b_1^{\text{Coen}k,r} = 0.19$
Cummins, Hassett and Hubbard (1996)	6	$I_{i,t}/K_{i,t-1} = b_0 + b_1\tilde{Q}_{i,t}$	Global Vantage USA 1987	Firm-level projecting out expectations (het. SEs)	0.603 (0.086)	$b \times \Omega$ (Lemma 4), $\Omega = 1.21$ (Cummins, Hassett and Hubbard, 1994): $-b_1^{\text{Coen}I(0)/K,r} = \chi b_1^{\text{Coen}k,r} = 0.73$
Zwick and Mahon (2017)		$\log I_{i,t} = b_0 + b_1 z_{i,t}$	SOI corporate sample	Four-digit NAICS with year and firm FE (cluster firm)		$b \times \delta(1-\tau z)/\tau$ (Lemma 5), $z = 0.907, \delta = 0.1$ (table 2), $\tau = 0.35$ (statutory):
	3(1)		Pooled		3.69 (0.53)	$-b_1^{\text{Coen}I(0)/K,r} = \chi b_1^{\text{Coen}k,r} = 0.72$
	6(1)		Small firms		6.29 (1.21)	$-b_1^{\text{Coen}I(0)/K,r} = \chi b_1^{\text{Coen}k,r} = 1.23$
	6(2)		Large firms		3.22 (0.76)	$-b_1^{\text{Coen}I(0)/K,r} = \chi b_1^{\text{Coen}k,r} = 0.63$
Curtis et al. (2021)	2(3)	$k_i = b_0 + b_1 [\mathbb{I}z \leq P_{33}(z)]$	Census ASM, CM 2001-2011	Long-difference	0.1047 (0.0192)	$b \times \Delta_{2001,2011}\Delta_{z \leq P_{33}(z), z > P_{33}(z)} \times -(1-\tau z)/\tau$ (Lemma 5), $\Delta_{2001,2011}\Delta_{z \leq P_{33}(z), z > P_{33}(z)} = 0.034$, $z = 0.84$ (Appendix B), $\tau = 0.35$ (statutory): $b_1^{\text{Coen}k(10),r} = \left(1 - e^{10\chi}\right) b_1^{\text{Coen}k,r} = -6.21$
Chodorow-Reich et al. (2025)	3(3)	$\log I_{i,t} = b_0 + b_1 \log \Omega_{i,t}$	SOI C-corporate sample, 2015-19	Firm-level in first-differences (het. SEs)	-4.27 (0.51)	$-b \times \delta$ (Lemma 3), $\delta = 0.1$ (Zwick and Mahon, 2017): $-b_1^{\text{Coen}I(0)/K,r} = \chi b_1^{\text{Coen}k,r} = 0.427$
Kennedy et al. (2022)	6(3)	$I_{i,t}/K_{i,t-1} = b_0 + b_1 \log \Omega_{i,t}$	SOI corporate sample, 2013-2019	Instrument using C-corp. indicator × post-2017 (cluster firm)	0.445 (0.070)	$-b$ (Lemma 3): $-b_1^{\text{Coen}I(0)/K,r} = \chi b_1^{\text{Coen}k,r} = 0.445$

information essentially removes the $\lambda_{i,t-2}$ term from the regressor altogether. As a result, their specification in fact is equation (40d) except with $-\Omega_{i,t}$ as the regressor, and Lemma 4 applies. The Cummins, Hassett and Hubbard (1994, p. 30) interpretation of their results in terms of the magnitude of adjustment costs is therefore incorrect. Rather, focusing on the years with major tax reforms, their estimates map into values of $-b_1^{\text{Coen}I(0)/K,r} = \chi b_1^{\text{Coen}k,r}$ ranging from 0.66-1.18. Cummins, Hassett and Hubbard (1996, table 6) implement the same specification and find a value of 0.73.

Cummins, Hassett and Hubbard (1994, table 9) estimates equation (40e). Using Lemma 4, these estimates map into values of $\chi b_1^{\text{Coen}k,r}$ ranging from 0.14 to 0.19 for major tax reform years, notably smaller than the values implied by their table 5. This difference is surprising, since the specifications should differ only in that the regressor in equation (40e) is $R/\Omega = (\rho+\delta)$ multiplied by the regressor in equation (40d). If $\rho + \delta$ were fixed across firms and ignoring the differences between their $\tilde{Q}$ and Ω, then $plim\ b_1^{\text{Coen}I(0)/K,R} = plim\ b_1^{\text{Coen}I(0)/K,\Omega}/(\rho+\delta)$. Instead, Cummins, Hassett and Hubbard (1994) obtain coefficients of similar magnitude. One possible explanation is attenuation bias; Cummins, Hassett and Hubbard (1994) use firm-specific ρ based on bond yields and δ based on book capital. If these values have measurement error, the estimation of $b_1^{\text{Coen}I(0)/K,R}$ will be attenuated. Alternatively, the difference may stem because their table 5 uses total investment while their table 9 uses equipment investment in the dependent variable.

Zwick and Mahon (2017) study the introduction of bonus depreciation in the early 2000s. Their specification is equation (40f). Applying Lemma 5, the implied $\chi b_1^{\text{Coen}k,r}$ pooling over all firms is 0.72. They also find important hetergeneity, with $\chi b_1^{\text{Coen}k,r} = 1.23$ for smaller firms and 0.63 for larger firms.

Curtis et al. (2021) also study the introduction of bonus depreciation but look at outcomes after 10 years. Using Lemma 5, their estimate for log capital translates into a value of $(1 - e^{10\chi})\, b_1^{\text{Coen}k,r} = -6.21$. This number is not however directly comparable to the estimation in Zwick and Mahon (2017) as the Curtis et al. (2021) sample contains only manufacturing firms. For values of $\chi \subseteq (1, 1.8)$ (see Section 4 for discussion of these values), the Curtis et al. (2021) coefficient implies $\chi b_1^{\text{Coen}k,r} \subseteq (0.98, 1.34)$.

Chodorow-Reich et al. (2025) and Kennedy et al. (2022) study variation induced by the TCJA.

Using firm-level variation for C corporations without international presence (to avoid complications from the TCJA's changes to international taxation), Chodorow-Reich et al. (2025) implement equation (40b). Applying Lemma 3, their regression coefficient translates into $\chi b_1^{\text{Coen}k,r} = 0.427$.

Kennedy et al. (2022) compare C and S corporations, as the corporate rate cut in TCJA applied only to the former. Their specification is equation (40c). Applying Lemma 3, their regression coefficient translates into $\chi b_1^{\text{Coen}k,r} = 0.445$.

Summary. Comparing across the implied values of $-plim b_1^{\text{Coen}I(0)/K,r} = \chi b_1^{\text{Coen}k,r}$ in Table 2 gives the contours of the Hassett and Hubbard (2002) range of -0.5 to -1 for the short-run response. However, I report values for the semi-elasticity of investment, not the elasticity; rescaling the values in Table 2 by I/K would imply much larger elasticities. This difference does not reflect uniformly larger responses of investment to the more recent episodes of bonus depreciation and the TCJA than the earlier studies reviewed in Hassett and Hubbard (2002). Rather, in several cases my re-analysis contains adjustments to earlier estimates. The table also contains notable extremes. Cummins, Hassett and Hubbard (1994, table 9) implies values for $\chi b_1^{\text{Coen}k,r}$ below 0.2. This study estimates equation (40e) with $R_{i,t}$ as the main regressor, however, and thus has the concern of attenuation bias stemming from the non-tax component of the user cost. Only Cummins, Hassett and Hubbard (1994, table 5, 1963 and 1987), Zwick and Mahon (2017, small firms), and Curtis et al. (2021) find values above 0.75. A central tendency range of -0.25 to -0.75 therefore summarizes empirical evidence of the Coen (1969) cross-firm short-run semi-elasticity of investment to the user cost.

3.3 Estimates of Hybrid Specifications

Motivated by the possibility of measurement error in λ, Desai and Goolsbee (2004) and Edgerton (2010) split Q to allow different coefficients multiplying the $\lambda_{i,t}/(1-\tau_{i,t})$ and $\Omega_{i,t}$ components:[18]

$$I_{i,t}/K_{i,t-1} = b_0^{\text{hybrid}} + b_1^{\text{hybrid}} \frac{\lambda_{i,t}}{1-\tau_{i,t}} + b_2^{\text{hybrid}} \Omega_{i,t} + e_{i,t}. \tag{42}$$

This split is formally an over-identification test of the Summers (1981) specification, which requires $b_1 = -b_2$. If this condition fails, however, no clear structural interpretation of either coefficient

[18] This exercise was first proposed by Caballero (1994) in his published comment on Cummins, Hassett and Hubbard (1994).

Table 3: Estimates of the Hybrid Specification

Article	Table (col.)	Estimating equation	Data	Variation	b_1 (s.e.)
Desai and Goolsbee (2004)	8(1)	$I_{i,t}/K_{i,t-1} = b_0 + b_1\lambda_{i,t} + b_2\Omega_{i,t}^{\text{equipment}} + b_3\frac{CF_{i,t-1}}{K_{i,t-1}}$	U.S. Compustat annual 1962-2003	Four-digit SIC with year and firm FE (cluster by firm); includes control for structures tax term	$b_1 =$ 0.0231 (0.0011), $b_2 =$ −0.8895 (0.3173)
Edgerton (2010)	3(2)	$I_{i,t}/K_{i,t-1} = b_0 + b_1\lambda_{i,t} + b_2\Omega_{i,t}^{\text{equipment}}$	North America Compustat annual 1967-2005	Four-digit SIC with year and firm FE (cluster by firm); includes control for non-taxable status, its interaction with $\Omega_{i,t}$, and structures tax term	$b_1 =$ 0.038 (0.001), $b_2 =$ −0.846 (0.323)

exists:

Lemma 6 *In the environment of Section 2.5 with quadratic adjustment costs in capital, plim* $b_1^{hybrid} = -$*plim* $b_2^{hybrid} = 1/\phi$*, where* ϕ *scales the adjustment cost in equation (26). In the limit where* $\lambda_{i,t}$ *is only noise, plim* $b_1^{hybrid} = 0$ *and plim* $b_2^{hybrid} = -(\chi_i\Omega_i)$ *plim* $b_1^{Coenk,r}$ *as in Lemma 4. If* $\lambda_{i,t}$ *contains both signal and classical measurement error and* $Cov(\lambda_{i,t}, \Omega_{i,t}) < 0$*, then* $|$*plim* $b_2^{hybrid}| >$ $|$*plim* $b_1^{I/K,Q}|$*.*

Summary. In practice, Desai and Goolsbee (2004) and Edgerton (2010) find much larger (in absolute value) coefficients multiplying the $\Omega_{i,t}$ component and near zero coefficients multiplying $\lambda_{i,t}/(1-\tau_{i,t})$. Desai and Goolsbee (2004) incorrectly interpret this result as the coefficient multiplying $\Omega_{i,t}$ providing a more accurate measure of adjustment costs.[19] While the interpretation of attenuation bias affecting b_1^{hybrid} may be correct, it does not follow that b_2^{hybrid} then recovers the adjustment cost parameter. In the extreme case where measurement of $\lambda_{i,t}/(1-\tau_{i,t})$ results in only noise, the regression instead recovers the Coen (1969) elasticity. Applying this interpretation and using $\Omega = 1.25$ (see Table 2, Cummins, Hassett and Hubbard (1994, table 5)) would imply $\chi b_1^{\text{Coen}k,r} \approx 0.7$, in the range of values found in Table 2.

[19] Desai and Goolsbee (2004, p. 315): "the model predicts that these coefficients should be of the same magnitude as those on tax-adjusted q [λ in my notation], but of opposite sign. Here, instead, the coefficients on the equipment tax term are considerably larger. With measurement error in q, the coefficient on the tax term may provide a more realistic estimate of the true coefficient. Such a coefficient is considerably closer to 1 and, consequently, corresponds to more realistic estimates of adjustment costs."

3.4 Estimates of the Eisner and Nadiri (1968) Specification

Table 4 reviews articles that estimate variants of the equations:

$$k_{i,t} = b_0^{\text{E-N}k,r} + b_1^{\text{E-N}k,r} r_{i,t} + b_2^{\text{E-N}k,r} y_{i,t} + e_{i,t}, \tag{43a}$$

$$\Delta\left(k_{i,t} - y_{i,t}\right) = b_0^{\text{E-N}CRS} + b_1^{\text{E-N}CRS} r_{i,t} + b_2^{\text{E-N}CRS}\left(k_{i,t-1} - y_{i,t-1}\right) + b_3^{\text{E-N}CRS}\Delta r_{i,t} + e_{i,t}, \tag{43b}$$

$$I_{i,t}/K_{i,t-1} = b_0^{\text{E-N}DLM} + \sum_{h=0}^{H} b_{1,h}^{\text{E-N}DLM}\Delta r_{i,t-h} + \sum_{h=0}^{H} b_{2,h}^{\text{E-N}DLM}\Delta y_{i,t-h} + e_{i,t}, \tag{43c}$$

$$\begin{aligned} k_{i,t} = {} & b_0^{\text{E-N}ECM} + b_1^{\text{E-N}ECM} r_{i,t-1} + b_2^{\text{E-N}ECM} y_{i,t-1} + b_3^{\text{E-N}ECM} k_{i,t-1} \\ & + \sum_{h=0}^{H-1}\left(b_{1,h}^{\text{E-N}ECM}\Delta r_{i,t-h} + b_{2,h}^{\text{E-N}ECM}\Delta y_{i,t-h}\right) + e_{i,t}. \end{aligned} \tag{43d}$$

Two key features distinguish equations (43a) to (43d) from the Coen (1969) specifications. First, the inclusion of firm log revenue $y_{i,t}$ as a second regressor or the capital-output ratio as the dependent variable. Second, the explicit focus on long-run outcomes either by estimating only across steady states or through inclusion of dynamic terms. As a result, they identify the elasticity of substitution η. Equation (43a) estimated across steady states is the most straightforward application. Using equation (22):

Lemma 7 *In the environment of Section 2.4 with CES production, equation (43a) estimated across steady states recovers plim* $b_1^{\text{E-N}k,r} = -\eta$ *and plim* $b_2^{\text{E-N}k,r} = \eta + (1-\eta)/(\alpha+\beta)$.

To take the Cobb-Douglas case for simplicity, comparing Lemmas 2 and 7 shows that controlling for Y or not changes the steady state elasticity from -1 to $-1/(1-\gamma)$, which may be much larger than -1 in absolute value.[20]

Chirinko, Fazzari and Meyer (2011) implement equation (43a) by differencing across five-year averages of firm-level capital and tax-adjusted user cost. Treating the different five-year periods as distinct steady states, they find an elasticity of substitution of $\eta = 0.367$ and near constant (in fact, increasing) returns to scale in the revenue function of $\alpha + \beta = 1.135$.

[20] At short horizons, equation (22) still holds for a suitably defined user cost $R_{i,t}$ that includes the marginal adjustment costs. In this case, the appropriate control is the output $y_{i,t}$ in the period in which the capital is used. Thus, with time-to-build that delays the effect of investment on output, the appropriate Eisner and Nadiri (1968) specification control is future output. Of course, this specification also requires $r_{i,t}$ rather than the steady state r_i as the main regressor and capital rather than investment as the dependent variable, making clear the differences between Coen (1969) and Eisner and Nadiri (1968) specifications even at short horizons.

Table 4: Estimates of the Eisner and Nadiri (1968) Specification

Article	Table (col.)	Estimating equation	Data	Variation	b (s.e.)	Transformation
Caballero, Engel and Haltiwanger (1995)	Fig. 4	$\Delta(k_{i,t} - y_{i,t}) = b_0 + b_1 r_{i,t} + b_2(k_{i,t-1} - y_{i,t-1}) + b_3 \Delta r_{i,t}$	LRD manufacturing 1972-1988	2-digit SIC industry, constrain b_1, b_2, b_3 by 2 digit sector	Not reported	b_1/b_2 (Lemma 8): $\eta \subseteq [-0.01, -2]$ (mean=-1)
Chirinko, Fazzari and Meyer (1999)	4(orth. dev.)	$I_{i,t}/K_{i,t-1} = b_0 + \sum_{h=0}^{H} b_{1,h} \Delta r_{i,t-h} + \sum_{h=0}^{H} b_{2,h} \Delta y_{i,t-h}$	Compustat annual 1981-1991	2-digit SIC industry, Arellano and Bover (1995) orthogonal deviation estimator with $H = 2$ for b_1, $H = 4$ for b_2, control for cash flow	$\sum_h b_{1,h} = -0.26(0.046)$, $\sum_h b_{2,h} = 0.209(0.072)$	$\eta = -\sum_h b_{1,h}, \alpha + \beta = (1 \sum_h b_{1,h}) / \sum_h (b_{1,h} + b_{2,h})$ (Lemma 9): $\eta = 0.26, \alpha + \beta < 0$
Chirinko, Fazzari and Meyer (2011)	1(1)	$k_{i,t} = b_0 + b_1 r_{i,t} + b_2 y_{i,t}$	Compustat + DRI 1972-1991	Differences of averages over 1972-77, 1978-84, 1985-91, tax-adjusted user cost from DRI	$b_1 = -0.367(0.068), b_2 = 0.925(0.038)$	$\eta = -b_1, \alpha + \beta = (1 + b_1)/(b_1 + b_2)$ (Lemma 7): $\eta = 0.367, \alpha + \beta = 1.135$
Dwenger (2014)	5(1)	$k_{i,t} = b_0 + b_1 r_{i,t-1} + b_2 y_{i,t-1} + b_3 k_{i,t-1}$	Hoppenstedt (German accounting data) 1987-2007	2-digit industry, control lag changes in r and y	$b_1 = -0.606(0.107)$, $b_2 = 0.406(0.075), b_3 = 0.352(0.067)$	$\eta = -b_1/(1 - b_3), \alpha + \beta = b_2/(1 - b_3)$ (Lemma 10): $\eta = 0.935, \alpha + \beta = 0.623$

Equations (43b) to (43d) reflect alternative approaches to allowing for non-instant adjustment of capital to its desired level in annual panel data. Caballero, Engel and Haltiwanger (1995) estimate the cointegration model (43b) using data from the U.S. manufacturing sector. They motivate a steady state relationship between the capital-output ratio and user cost by starting from a Cobb-Douglas production function and an *ad hoc* coefficient scaling the user cost. Thus, instead of $k_i - y_i = \log \alpha - r_i$ (see equation (12)), they assume $k_i - y_i = \log \alpha - cr_i$ for a scalar c. One can instead rigorously derive this relationship by starting from CES with constant returns to scale (see Appendix B):

Lemma 8 *In the environment of Section 2.4 with CES production and constant returns to scale in the revenue function, $\alpha + \beta = 1$, equation (43b) recovers $\eta = b_1^{E\text{-}NCRS}/b_2^{E\text{-}NCRS}$.*

They find implied values of η between 0 and 2 across 2 digit manufacturing industries, with a mean η of 1.

Equations (43c) and (43d) also do not impose the quadratic adjustment cost environment of Section 2.5. Instead, they make alternative *ad hoc* assumptions about how investment or capital depends on lagged values of "desired capital", denoted by $K_{i,t}^*$ and defined as the solution to equation (22) taking $Y_{i,t}$ as given. Chirinko, Fazzari and Meyer (1999) show (see Appendix B):

Lemma 9 *Assume $I_{i,t}/K_{i,t-1} = \delta + \sum_{h=0}^{H} \omega_h \Delta k_{i,t-h}^*$, where $\sum_{h=0}^{H} \omega_h = 1$. Then in the environment of Section 2.4 with CES production, equation (43c) recovers $\sum_{h=0}^{H} b_{1,h}^{E\text{-}NDLM} = -\eta$ and $\sum_{h=0}^{H} b_{2,h}^{E\text{-}NDLM} = \eta + \frac{1-\eta}{\alpha+\beta}$.*

Chirinko, Fazzari and Meyer (1999) analyze variation in the user cost due to tax changes and other factors. Their preferred specification uses lagged values as instruments (Arellano and Bover, 1995). They find an elasticity of substitution $\eta = 0.26$ and negative implied returns to scale.[21]

Dwenger (2014) is the lone exception to this section's focus on results using U.S. data. The reasons are that this study has featured prominently in the U.S. policy debate (see e.g. Council

[21] Illustrating some of the difficulties in comparing across studies, Chirinko, Fazzari and Meyer (1999, pp. 69-71) directly compares their results to Cummins, Hassett and Hubbard (1994) without taking account of either the difference between the distributed lag specification in Chirinko, Fazzari and Meyer (1999) and the one-year specification in Cummins, Hassett and Hubbard (1994) or the importance of controlling for firm revenue. The same comparison is made in Chirinko (2008).

of Economic Advisers, 2019; Congressional Research Service, 2024; Council of Economic Advisers, 2025) and that it offers a methodological critique of and alternative to the distributed lag assumption in Chirinko, Fazzari and Meyer (1999). Dwenger instead shows (see Appendix B):

Lemma 10 *Assume* $k_{i,t} = \phi k_{i,t-1} + \sum_{h=0}^{H} \omega_h k^*_{i,t-h}$, *where* $\sum_{h=0}^{H} \omega_h = 1 - \phi$. *Then in the environment of Section 2.4 with CES production, equation* (43d) *recovers* $b_1^{E\text{-}NECM}/(1 - b_3^{E\text{-}NECM}) = -\eta$ *and* $b_{2,h}^{E\text{-}NDLM}/(1 - b_3^{E\text{-}NECM}) = \eta + \frac{1-\eta}{\alpha+\beta}$.

Dwenger (2014) estimates equation (43d) using German data and finds $\eta = 0.935, \alpha + \beta = 0.623$.[22]

Curtis et al. (2021) also merit mention in a discussion of the elasticity of substitution. As described above, they estimate a 10 year firm-level response of log capital to bonus depreciation. They also estimate the 10 year response of log employment and find a response as high or higher than the capital response. Across steady states, equations (6a), (9), (21a) and (21b) give $dk_i - d\ell_i = -\eta\,(dr_i - dw)$. If dw doesn't vary across firms due to a common labor market and the 10 year response reflects the new steady state, then this result implies an elasticity of substitution $\eta \leq 0$.

Summary. In summary, estimates of the Eisner and Nadiri (1968) specification holding revenue fixed yield values for the elasticity of substitution between capital and labor stretching from 0.3 to the Cobb Douglas value of 1.

3.5 Estimates of Asset-Level Specifications

All of the studies reviewed so far use variation at the level of the firm or industry. An alternative approach uses variation and outcomes at the asset class level:

$$I_{j,t}/K_{j,t-1} = b_0^{\text{Asset } I/K,R} + b_1^{\text{Asset } I/K,R} R_{j,t} + e_{j,t}, \tag{44}$$

where the index j rather than i indicates asset rather than firm-level analysis.

The interpretation of $b_1^{\text{Asset } I/K,R}$ hinges on the degree to which asset types correspond to specific industries. Insofar as they do, the variation in equation (44) mimics a Coen (1969) industry-level

[22] Again illustrating the difficulties in comparing across studies, Dwenger (2014, pp. 162-163) includes a literature review of "the user cost elasticity" that discusses quantitative results in Eisner and Nadiri (1968), Auerbach and Hassett (1992), Cummins, Hassett and Hubbard (1994, 1996), Caballero, Engel and Haltiwanger (1995), Chirinko, Fazzari and Meyer (1999), Chirinko, Fazzari and Meyer (2011), and Hassett and Hubbard (2002) without accounting for the key specification differences across these studies in whether they control for output or not and the adjustment horizon. Council of Economic Advisers (2019, 2025) and Hartley, Hassett and Rauh (2025) likewise compare without adjustment the results in Cummins, Hassett and Hubbard (1994) and Dwenger (2014).

analysis and Lemma 4 applies. If instead all industries use all types of capital with common, constant elasticity of substitution across asset types, then equation (44) more closely resembles an Eisner and Nadiri (1968) specification with substitution across capital types rather than between capital and labor. (In this case the regression intercept plays the role of controlling for total output.) However, because Lemma 7 relates long-run variation in log capital to the user cost, equation (44) does not afford easy interpretation in this case. U.S. Bureau of Economic Analysis (2025*a*) provides asset-by-industry data for 74 industries and 94 asset types. For the median asset type, roughly half of economy-wide capital of that type concentrates in one industry. For the median industry, close to 40% of its capital is of one type. These concentration levels may support a Coen (1969) interpretation but also suggest prudence in comparing to firm-level analyses.

Table 5 reports results from two studies using asset-level variation. Auerbach and Hassett (1991) analyze investment patterns across asset classes after the 1986 reform and find assets with larger declines in the user cost had larger increases in investment.[23] Applying a Coen (1969) interpretation, their coefficient implies $\chi b_1^{\text{Coen}k,r} = 0.15$, below the range established in Section 3.2.

Hartley, Hassett and Rauh (2025) use variation induced by the TCJA and report separate regressions for changes in the investment-capital ratio from 2016 to each year in 2018-2023. Applying a Coen (1969) interpretation, their 2018 coefficient translates into $\chi b_1^{\text{Coen}k,r} = 0.35$. Dividing each horizon's rescaled coefficient by $e^{\chi h}$ and averaging across their coefficients for 2018-2023, for $\chi \subseteq (1, 1.8)$ the translated values imply $\chi b_1^{\text{Coen}k,r} \subseteq (0.51, 0.65)$, in the upper-middle part of the range shown in Table 2.[24]

Summary. Interpretation of asset-level specifications hinges on the degree to which asset types correspond to specific industries. Compared to the Coen (1969) estimates reported in Table 2, the

[23] Bosworth (1985) is the first article of which I am aware to examine the cross-sectional pattern of investment following a tax reform. It reported correlations of investment surprises and tax changes and concluded that non-tax forces dominated investment in the years after the 1981 and 1982 tax changes.

[24] Hartley, Hassett and Rauh (2025, abstract) conclude that their results are "larger than prior estimates of the responsiveness of investment with respect to the user cost of capital." Their conclusion differs from mine because they compare their asset-level regression coefficients to estimates of the elasticity of substitution between capital and labor based on the Eisner and Nadiri (1968) specification in Dwenger (2014) and Bitros and Nadiri (2017), as well as to only Cummins, Hassett and Hubbard (1994, table 9) in Table 2 (Hartley, Hassett and Rauh, 2025, p.13). They also compare their implied elasticity $d \log I_j / dr_j$ of -1.8 to -3.3 (obtained from multiplying their regression coefficients by the sample average of $R/(I/K)$) to a value of -0.7 reported in Congressional Budget Office (2018*b*). As discussed in Section 5.5, CBO applies that value to compute the elasticity holding output fixed and subsequently allows capital to adjust as output increases; it thus cannot be directly compared to an asset-level specification.

Table 5: Estimates of Asset-Level Specifications

Article	Table (col.)	Estimating equation	Data	Variation	b (s.e.)	Transformation
Auerbach and Hassett (1991)	7(3)	$I_{i,t}/K_{i,t-1} = b_0 + b_1 R_{i,t}$	BEA equipment by asset type 1987	Asset level weighted by investment, projecting out expectations	-0.82 (0.26)	$-b \times R$ (Lemma 4), $R = 0.226$ (Appendix B): $-b_1^{\text{Asset } I(0)/K,r} = \chi b_1^{\text{Coen}k,r} = 0.15$
Hartley, Hassett and Rauh (2025)		$I_{i,t+h}/K_{i,t+h-1} = b_0 + b_1 R_{i,t}$	BEA Fixed Asset Tables	Asset-level in differences from 2016 (het. SEs)		$-b \times R$ (Lemma 4), $R = 0.2058$ (Appendix table 2):
	1(2)		2018		-1.689 (0.890)	$-b_1^{\text{Asset } I(0)/K(0),r} = \chi b_1^{\text{Coen}k,r} = 0.35$
	1(3)		2019		-1.057 (0.847)	$-b_1^{\text{Asset } I(1)/K(1),r} = \chi e^{\chi} b_1^{\text{Coen}k,r} = 0.22$
	1(4)		2020		-1.115 (1.113)	$-b_1^{\text{Asset } I(2)/K(2),r} = \chi e^{2\chi} b_1^{\text{Coen}k,r} = 0.23$
	1(5)		2021		-2.873 (1.166)	$-b_1^{\text{Asset } I(3)/K(3),r} = \chi e^{3\chi} b_1^{\text{Coen}k,r} = 0.59$
	1(6)		2022		-3.053 (1.180)	$-b_1^{\text{Asset } I(4)/K(4),r} = \chi e^{4\chi} b_1^{\text{Coen}k,r} = 0.63$
	1(7)		2023		-1.282 (1.154)	$-b_1^{\text{Asset } I(5)/K(5),r} = \chi e^{5\chi} b_1^{\text{Coen}k,r} = 0.26$

asset-level studies translate into values in the lower or middle part of the range.

4 Implied Parameters

This section asks what light the empirical evidence summarized in Section 3 can shed on primitive parameters. For this purpose, I consider a "representative" firm and do not index parameters with i. I externally calibrate the labor share of revenue $\beta^* = 0.65$ and for simplicity set $\beta = \beta^*$. Where necessary, I also set the discount rate $\rho = 0.06$ and the user cost $R = 0.2$. While these values may have changed over time, I view the sampling uncertainty in the empirical studies as likely to swamp variation due to changes in these parameters and it facilitates comparisons to keep them fixed.[25] This leaves the following parameters: the adjustment cost scalar ϕ, the revenue elasticity of capital $\alpha = \alpha^*$, and the capital-labor substitution elasticity η.

Table 1 reviewed studies that estimate the adjustment cost parameter ϕ. Using tax variation as an instrument, Cummins, Hassett and Hubbard (1996, table 7) found a value $\phi = 1.5$. The other studies found much larger values, but may suffer from attenuation bias.

Table 4 reviewed studies that estimate the capital-labor substitution elasticity η. Values ranged from 0.3 to above 1, with 0.9 being from the most recent study. By comparison, Chirinko (2008) reviews both tax and non-tax based approaches and argues for a value between 0.4 and 0.6 while Knoblach, Roessler and Zwerschke (2020) conduct a meta-analysis and argue for a value between 0.5 and 0.9. Congressional Budget Office (2018*b*) uses a value of 0.7, while Council of Economic Advisers (2019, 2025) use a value of 1.

Table 2 reviewed studies estimating variants of the Coen (1969) elasticity. For a long-run specification, these translate immediately into functions of α, β, and η. For a short-run specification, these also involve the eigenvalue χ given in equation (34) and hence the adjustment cost parameter ϕ. Using equations (34) and (37) and Lemma 4, for example:

$$plimb_1^{\text{Coen}I(0)/K,r} = -\chi plimb_1^{\text{Coen}k,r} = \left(\frac{\rho}{2} - \sqrt{\left(\frac{\rho}{2}\right)^2 - \left(\frac{dk_i}{dr_i}\right)^{-1}\frac{R}{\phi}}\right) \times \left(\frac{dk_i}{dr_i}\right), \tag{45}$$

where dk_i/dr_i is given by equation (25).

[25] For example, the corporate labor share in the U.S. has trended down from roughly 0.65 in the 1980s to 0.6 in the 2010s (Karabarbounis and Neiman, 2014), the cost of debt has declined (Gormsen and Huber, 2023), and the user cost has declined due to a shrinking tax term.

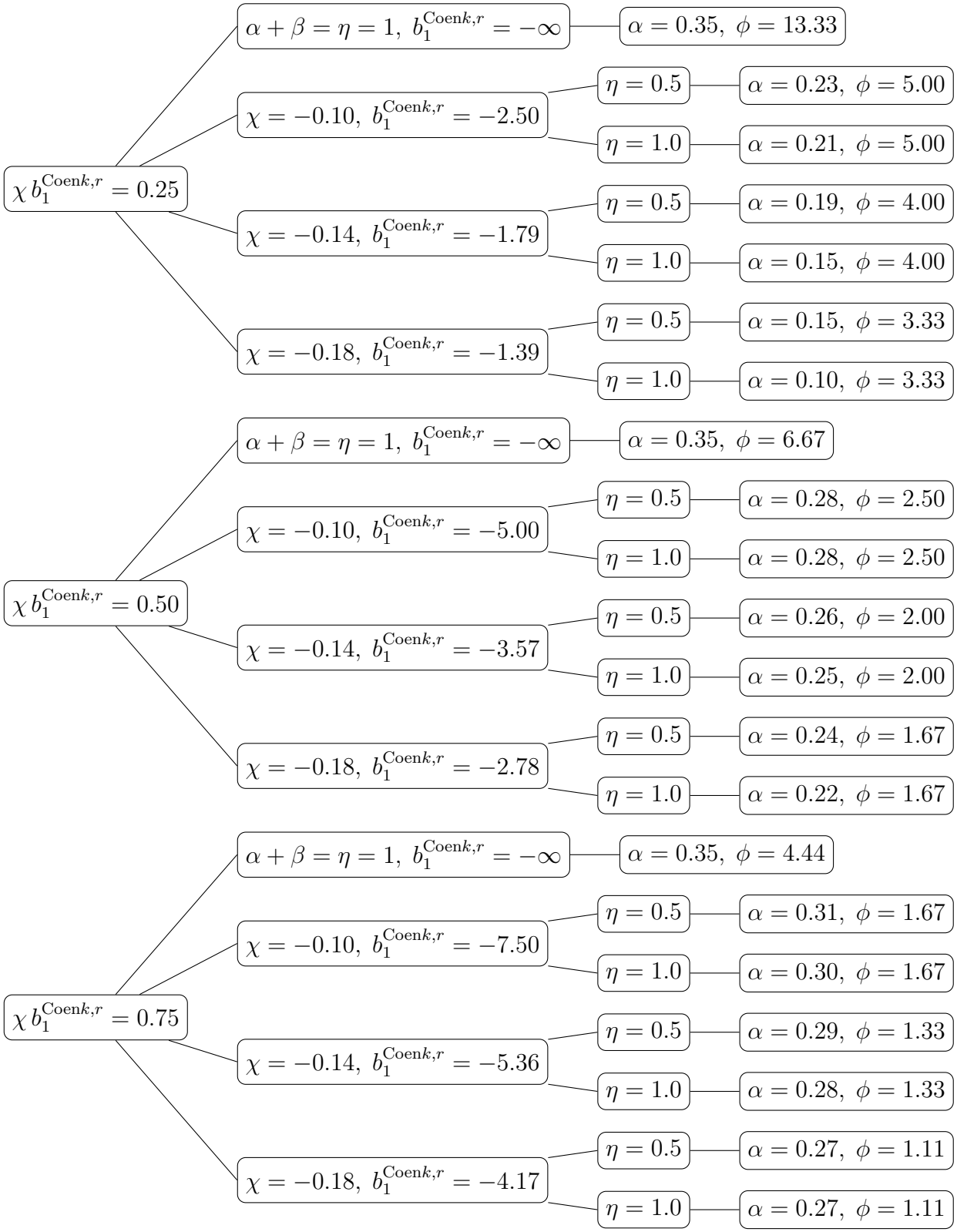
Two approaches exist to infer primitive parameters from the short-run coefficients. One approach, pursued in Auerbach and Hassett (1992), assigns values of α, β, and η, which collectively characterize dk_i/dr_i, and backs out ϕ using equation (45). The alternative, pursued in Chodorow-Reich et al. (2025), sets χ directly, recovers the implied long-run coefficient and the parameter values α, β, and η, and backs out ϕ using the expression for χ in equation (34). The drawback of the second approach is that χ is not a deep structural parameter (in fact it depends on policy—see equation (34)). The advantages are: (i) calibration of χ can incorporate external information on adjustment costs and transition dynamics such as from moments of the firm investment distribution, (ii) the ratio of the short-to-long-run elasticity is a portable statistic that continues to apply under more complicated adjustment cost models than quadratic costs, and (iii) the transparency of setting χ directly allows readers to easily substitute their own preferred rescaling.

Figure 2 presents implications for α and ϕ under both approaches, taking as inputs various combinations of $-b_1^{\text{Coen}I(0)/K,r} = \chi b_1^{\text{Coen}k,r}$, χ, and η. The figure contains "trees" based on representative values for the short-run semi-elasticity of the investment-capital ratio to the user cost $\chi b_1^{\text{Coen}k,r}$ in Table 2: $\chi b_1^{\text{Coen}k,r} \in \{0.25, 0.5, 0.75\}$. The Auerbach and Hassett (1992) "branches" assume a Cobb-Douglas revenue function with constant returns to scale, $\alpha + \beta = \eta = 1$, such that equation (38) applies and $\phi = \rho / \left(R\chi b_1^{\text{Coen}k,r}\right)$. The Chodorow-Reich et al. (2025) branches consider $\chi \in \{0.1, 0.14, 0.18\}$ and $\eta \in \{0.5, 1\}$. The values of χ have the interpretation of the scaled ratio of the short-run to long-run impulse response shown in Figure 1(b). In that figure's calibration $\chi = 0.15$, with an impact response of 1.24% and long-run response of 0.84% yielding a ratio of $\chi/\delta = 1.5$. Thus, a value $\chi = 0.1$ implies a flat impulse response while $\chi = 0.18$ implies a more steeply declining impulse response function.[26] The values of $\eta \in \{0.5, 1\}$ span the Cobb-Douglas value of 1 and a lower elasticity of substitution as found in some of the studies in Table 4 and in the meta-analysis by Knoblach, Roessler and Zwerschke (2020).

Figure 2 contains several lessons. To start, the long-run Coen (1969) firm-level elasticity of capital to the user cost, $b_1^{\text{Coen}k,r}$, is always below -1 and sometimes substantially so. Equation (18) showed this inequality analytically in the Cobb-Douglas case, but it does not necessarily carry

[26] Chodorow-Reich et al. (2025) argue that $\chi = 0.14$ is a plausible value based on calibrations of firm-level adjustment costs such as in Winberry (2021). Their analysis focuses on the ratio of the short-to-long run elasticity χ/δ. Using $\delta = 0.1$, this ratio is 1.4, consistent with their analysis of Winberry (2021).

Figure 2: Coen (1969) Specification Implied Parameters



Notes: Each "tree" starts from a value for the short-run semi-elasticity of I/K to the user cost r of $\chi b_1^{\text{Coen}k,r}$. The "branches" either set the total returns to scale $\alpha+\beta$ and elasticity of substitution between capital and labor η to 1 or values for the short-to-long-run ratio χ and for η. The "leaves" give the implied values for the revenue elasticity of capital α and the adjustment cost scalar ϕ.

over to the CES case, where small enough η and α can make the long-run elasticity close to zero. For the mid-point short-run semi-elasticity of investment and the values of η considered, the long-run elasticity is around -3 or below. This conclusion highlights the difference between the long-run Coen (1969) elasticity and the elasticity of substitution between capital and labor and associated "neoclassical benchmark" of -1. Notably, it does not depend on the assumption of quadratic adjustment costs, but only the existence of some plausibly-valued scalar relating the short and long-run elasticities.

Second, a short-run value of $\chi b_1^{\text{Coen}k,r} = 0.25$ can imply quite low values of the capital revenue elasticity α. For $\chi b_1^{\text{Coen}k,r} \in \{0.5, 0.75\}$, the implied values of α range from 0.22 to 0.35 and the values of ϕ vary between 1 and 2.5. The upper bound for α comes from the constant returns to scale specification; in the remainder, α ranges from 0.22 to 0.31. This range implies total returns to scale $\alpha + \beta$ between 0.87 and 0.96, not too far from constant returns. The fact that ϕ does not vary with η follows from equation (34), which shows that χ depends only on $\rho, R, b_1^{\text{Coen}k,r}$, and ϕ.

Third, the values of α vary only slightly with η within a χ branch of a tree. This result obtains because in these trees the total returns to scale are not too far from one (see equation (25)).

5 From Cross-sectional Studies to Aggregate Investment

This section explores what the parameter values found in Section 4, based on firm or asset-level regressions, imply for the aggregate long-run elasticity of capital to the user cost as well as the effect on aggregate output and wages. The firm-level and aggregate elasticities differ because in partial equilibrium the neoclassical firm faces flat factor supply curves, taking the wage as fixed, while in general equilibrium, factor supply curves may slope up.[27] Section 5.1 derives the general equilibrium Coen (1969) user cost elasticity and provides values consistent with the cross-sectional evidence. Section 5.2 shows that the aggregate user cost elasticity scales with the share of economic activity in the corporate sector for changes to corporate taxes only. Section 5.3 extends the analysis to allow for the interest rate or capital goods price to respond to higher investment demand. Section 5.4 gives formulas for the tax revenue response and shows that the dynamic

[27] Following this logic, if firms have monopsony power and face upward-sloping labor supply curves, the gap between the cross-firm and general equilibrium user cost elasticities of capital is reduced. Kennedy et al. (2022) and Curtis et al. (2021) both test for and find no evidence that their treated firms increase wages for most workers relative to control firms, despite their increasing relative employment.

component does not fully counteract the mechanical revenue loss in the current low tax regime of the U.S. Section 5.5 compares these results to the approaches in leading policy models.

5.1 The General Equilibrium User Cost Elasticity in the Neoclassical Model

Interest in the long-run aggregate elasticity dates to Hall and Jorgenson (1967), who as noted assumed an elasticity of capital of -1 and no effect on output. Their reply to the Coen (1969) critique anticipates some of the inconsistencies of subsequent approaches: "Another question which could be asked is the general equilibrium one: What were the overall effects of tax incentive policies, assuming no alternative compensatory policy? The answer waits for the development of a satisfactory model of general equilibrium in the United States economy" (Hall and Jorgenson, 1969, p. 394).

In fact, under some simplifying assumptions the Coen (1969) elasticity has an analytic general equilibrium counterpart. Thus, maintain the following assumptions in addition to the environment considered in Section 2:

1. Aggregate labor is fixed.

2. The economy consists of a large number of identical firms, all of which face the same tax schedule.

3. Firms face possibly downward-sloping demand curves with price elasticity of demand $\mathcal{M}/(\mathcal{M}-1) > 1$: $dy_{i,t} = -dp_{i,t}/(\mathcal{M}-1)$, where $P_{i,t}$ is the firm's output price (and recall that $Y_{i,t}$ is the firm's revenue).

Assumption 1 holds for example with balanced growth path preferences. Assumptions 1 and 2 together imply that each firm's labor input remains the same before and after a tax change. Assumption 2 also allows the dropping of i subscripts from parameters; I keep i subscripts on firm-level variables to distinguish them from aggregates without i subscripts. Totally differentiating the revenue function (1) across steady states and using the necessary conditions (6a) and (9) and

Assumption 3 gives the firm's physical output across steady states:[28]

$$dy_i - dp_i = \mathcal{M} dy_i = \mathcal{M}\alpha dk_i + \mathcal{M}\beta d\ell_i + \mathcal{M} a_i. \tag{46}$$

I will sometimes refer to $\mathcal{M}$ as the markup, as it equals the equilibrium markup when firms have price-setting power.[29]

Start with the Cobb Douglas case. The key insight to solving for the general equilibrium user cost elasticity directly is that that while the partial equilibrium revenue elasticity of capital holding the wage fixed is $\gamma \equiv \alpha/(1-\beta)$ (see equation (15)), the general equilibrium output elasticity holding labor fixed is $\mathcal{M}\alpha$ (see equation (46)). Let Y denote real aggregate corporate value-added. The Coen (1969) general equilibrium user cost elasticity follows from applying the chain rule using equation (46) to equation (12):

$$\frac{dk}{dr} = -1 + \frac{\partial y}{\partial k}|_{L \text{ fixed}} \times \frac{dk}{dr} = -\frac{1}{1 - \mathcal{M}\alpha} \leq -1. \tag{47}$$

Equation (47) gives the general equilibrium version of the Coen (1969) elasticity under Cobb-Douglas. I will refer to it as the Barro and Furman (2018) elasticity as these authors use it (with $\mathcal{M} = 1$) to model the aggregate effects of the TCJA.[30] Moving from the Coen (1969) elasticity identified from cross-firm responses to the Barro and Furman (2018) general equilibrium elasticity therefore requires relating γ to $\mathcal{M}\alpha$.

Similar calculations give the Barro and Furman (2018) general equilibrium elasticity with CES production. Specifically, using the general equilibrium output elasticity in equation (46) in the implicit user cost elasticity (24) gives:

$$\frac{dk}{dr} = \left(\left(1 + \frac{1-\eta}{(\alpha+\beta)\,\eta}\right)\mathcal{M}\alpha - \frac{1}{\eta}\right)^{-1} = -\frac{(\alpha+\beta)\,\eta}{(\alpha+\beta) - (1-(1-\alpha-\beta)\,\eta)\,\mathcal{M}\alpha}. \tag{48}$$

[28] That is: $dy_i = \frac{dY_i}{Y_i} = \frac{A_i F_K(K_i,L_i) K_i}{Y_i}\frac{dK_i}{K_i} + \frac{A_i F_L(K_i,L_i) L}{Y_i}\frac{dL_i}{L_i} + a_i = \alpha_i^* dk_i + \beta_i^* d\ell_i + a_i$. Setting $\alpha = \alpha^*$, $\beta = \beta^*$, and using $\mathcal{M} dy_i = dy_i - dp_i$ gives equation (46).

[29] Some of the studies reviewed in Section 3 exploit industry-level variation. In this case, the cross-sectional elasticities may still reflect downward-sloping demand even if no individual firm has price-setting power and charges a markup. Hence equations (47) to (50) still apply for an appropriately-calibrated demand elasticity.

[30] Barro and Furman (2018, with $\mathcal{M} = 1$) and Chodorow-Reich et al. (2025) both discuss versions of equation (47). The remaining results in this section are new, including the extension to CES with markups and non-constant returns to scale in the revenue function in equation (48), the extension to two sectors in Section 5.2, the analytic framework for crowd-out in the non-tax component of the user cost in Section 5.3, the revenue elasticity results in Section 5.4, and the quantitative explorations.

The output and wage elasticities follow from equation (46) and the first order condition (6a) $A_i F_L(K_i, L_i) = W$ using equation (21b) and $d\ell = 0$:

$$\frac{dy}{dr} = \mathcal{M}\alpha \times \frac{dk}{dr}, \tag{49}$$

$$\frac{dw}{dr} = \left(1 + \frac{1-\eta}{(\alpha+\beta)\,\eta}\right) \times \frac{dy}{dr}. \tag{50}$$

Importantly, output here refers to corporate value-added, since corporate taxes do not apply to output of the government, non-corporate, or household sectors. These formulas thus assume either uniform taxation of all output or full segmentation of labor markets across these sectors (see assumption 1), as otherwise the corporate sector could pull in labor. Section 5.2 relaxes this assumption.

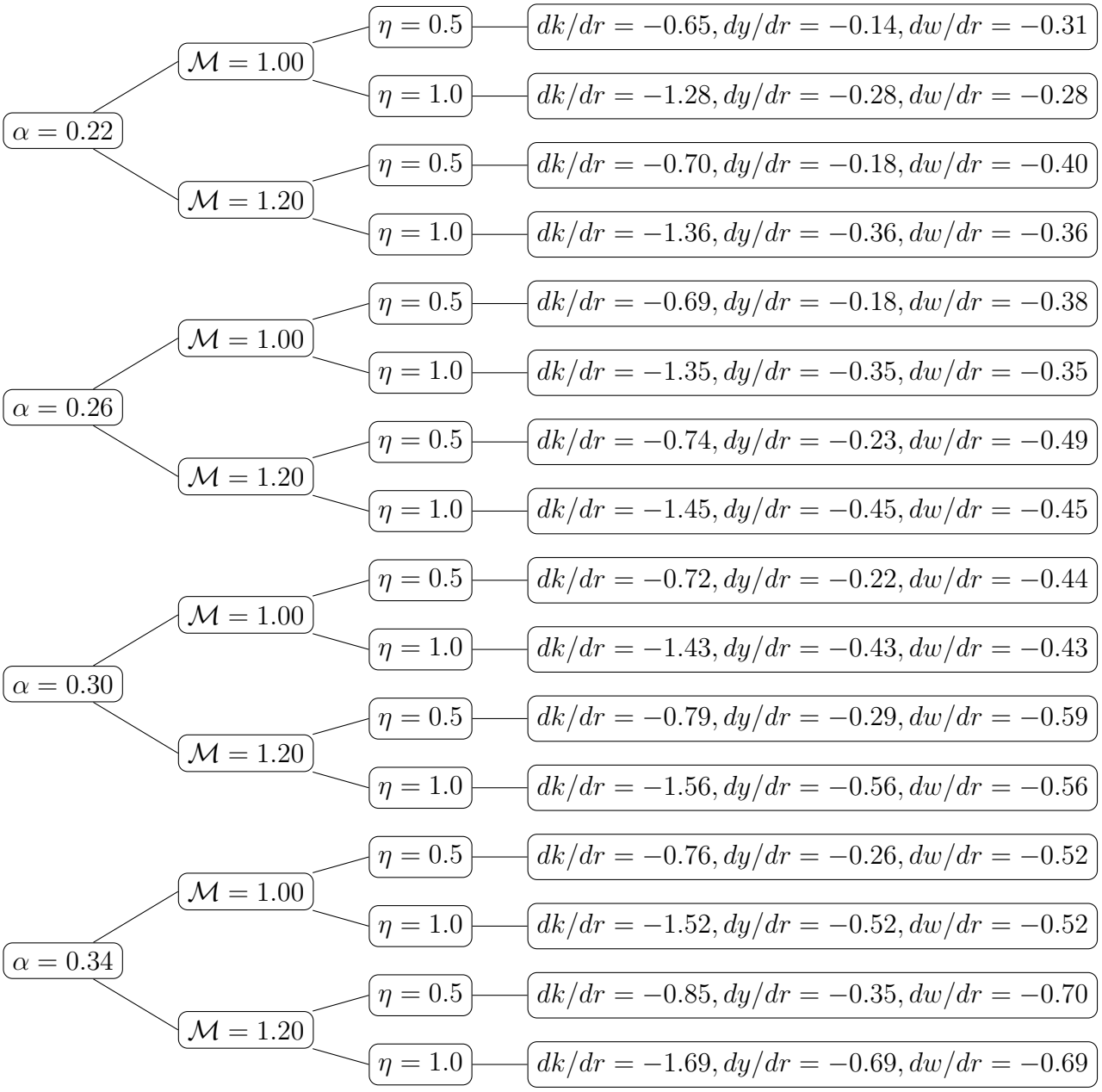
Using equations (48) to (50), Figure 3 gives values for the aggregate long-run elasticities of capital, output, and the wage consistent with the short-run cross-firm evidence. For concreteness, I consider values $\alpha \in \{0.22, 0.26, 0.3, 0.34\}$ (see Figure 2) and the equilibrium markup $\mathcal{M} \in \{1, 1.2\}$. I continue with a labor share $\beta = 0.65$ and the elasticity of substitution $\eta \in \{0.5, 1\}$.

Several lessons again emerge. First, under Cobb Douglas, the long-run Barro and Furman (2018) elasticity is always below -1, ranging from -1.3 to -1.7. This range is notably tighter than the range of partial equilibrium long-run Coen (1969) elasticities, which varied between -1.1 and $-\infty$ in Figure 2 (or -1.1 and -7.5 away from the constant returns case). The reason is that labor is a fixed factor in general equilibrium, which dampens the overall response. The elasticity of -1.6 used in the actual Barro and Furman (2018) article falls inside this range, illustrating again the difference between a general equilibrium elasticity and the "neoclassical benchmark" of -1.[31]

Second, the capital and output elasticities are smaller with $\eta = 0.5$, about half of their values with Cobb Douglas. Qualitatively, as the elasticity of substitution between capital and labor declines, the fixed factor of labor generates faster decreasing returns to capital accumulation. Quantitatively, with constant returns in the firm's revenue function, $\alpha + \beta = 1$, the Barro and Furman (2018) elasticity (48) simplifies to $-\eta/(1 - \mathcal{M}\alpha)$ and hence scales with η. The empirical evidence from Table 2 requires values of α large enough that this approximation roughly holds.

[31] Barro and Furman (2018, table 3) use a capital share of income of $\alpha = 0.38$ and no markup, implying an elasticity of $-1/(1 - 0.38) = -1.61$. Their table 5 reports their analysis of TCJA. In the case with permanent provisions, the user cost change is $d \log \Omega = -7.8\%$ and the change in capital is 12.7% (they report this as K/L but aggregate L is fixed), which gives a ratio of -1.62.

Figure 3: General Equilibrium Elasticities



Notes: Each "tree" starts from a value for the revenue elasticity of capital α. The "branches" set the markup $\mathcal{M}$ and the elasticity of substitution between capital and labor η. The "leaves" give the implied values for the long-run general equilibrium user cost elasticity of capital, output, and the wage.

Third, although capital and output respond much less when η is smaller, the wage elasticity is quite similar. Qualitatively, while capital responds less when $\eta < 1$, the wage responds more per unit of capital. Quantitatively, with constant returns in the firm's revenue function the general equilibrium wage elasticity simplifies to $-\mathcal{M}\alpha/(1-\mathcal{M}\alpha)$ and hence does not depend on η.

Fourth, the general equilibrium elasticities are increasing (in absolute value) in the markup $\mathcal{M}$. In partial equilibrium and fixing the returns to scale in the production function, a higher markup reduces the Coen (1969) elasticity because it lowers the returns to scale in the revenue function. Fixing the Coen (1969) elasticity as estimated in the data, however, a larger markup requires a larger output elasticity, increasing the general equilibrium response.

5.2 The General Equilibrium User Cost Elasticity with 2 Sectors

In many countries including the U.S., businesses have a choice of legal form of organization. Changes to the corporate tax rate apply only to firms incorporated as C-corporations. These firms accounted for 43% of private sector employment in 2022 (U.S. Census Bureau, 2022), making it of interest to relax assumption 2. Thus, modify assumption 2 to:

4. The economy consists of a C-corporate sector and non C-corporate sector, each of which consists of a large number of identical firms. Firms exogenously choose their sector. The production function parameters α, β, and η and technology A are common across the sectors.

5. Workers are indifferent between the two sectors.

Assumption 4 ensures that starting from *ex ante* identical taxation, firms in the two sectors look identical.[32]

Let $i \in \{c, n\}$ index variables for the C-corporate and non C-corporate sectors, respectively. Assumption 5 requires that the wage equalizes across sectors, with the labor market clearing condition $L_c + L_n = \bar{L}$. Let $\omega_c \equiv L_c/\bar{L}$ denote the share of labor in the C-corporate sector and set $\mathcal{M} = 1$ for notational simplicity. Let $\xi \equiv 1 + \frac{1-\eta}{(\alpha+\beta)\eta}$. Applying the first order conditions (6a) and (9), the CES revenue function derivatives (21a) and (21b), the output elasticity formula (46), and the labor market clearing condition across steady states with changes in the user cost of dr_c

[32]In fact, C-corporations have higher average capital per worker and productivity. The results in this section therefore serve as a benchmark without these differences as well as without an endogenous choice of corporate form.

and dr_n, respectively, gives a linear system of 7 equations in the 7 unknowns $dw, dk_i, d\ell_i, dy_i$:

$$dw = \xi dy_i - \frac{1}{\eta} d\ell_i, \ i \in \{c, n\}, \tag{51a}$$

$$dr_i = \xi dy_i - \frac{1}{\eta} dk_i, \ i \in \{c, n\}, \tag{51b}$$

$$dy_i = \alpha dk_i + \beta d\ell_i, \ i \in \{c, n\}, \tag{51c}$$

$$d\ell_c = -\left(\frac{1-\omega_c}{\omega_c}\right) d\ell_n. \tag{51d}$$

In addition, $dx = \omega_c dx_c + (1-\omega_c)\, dc_n$ for $x \in \{k, \ell, y\}$. The solution is (see equations (A.8) to (A.10) and (51c)):

$$\frac{dw}{dr_c} = -\left(\frac{\alpha\eta\xi}{1-\alpha\eta\xi}\right)\omega_c, \tag{52a}$$

$$\frac{dk_n}{dr_c} = \beta\eta\left(\frac{\eta\xi}{(\alpha+\beta)\,\eta\xi - 1}\right)\frac{dw}{dr_c}, \tag{52b}$$

$$\frac{dk_c}{dr_c} = \frac{dk_n}{dr_c} - \eta\left(\frac{\beta\eta\xi - 1}{(\alpha+\beta)\,\eta\xi - 1}\right), \tag{52c}$$

$$\frac{d\ell_n}{dr_c} = \eta\left(\frac{1-\alpha\eta\xi}{(\alpha+\beta)\,\eta\xi - 1}\right)\frac{dw}{dr_c}, \tag{52d}$$

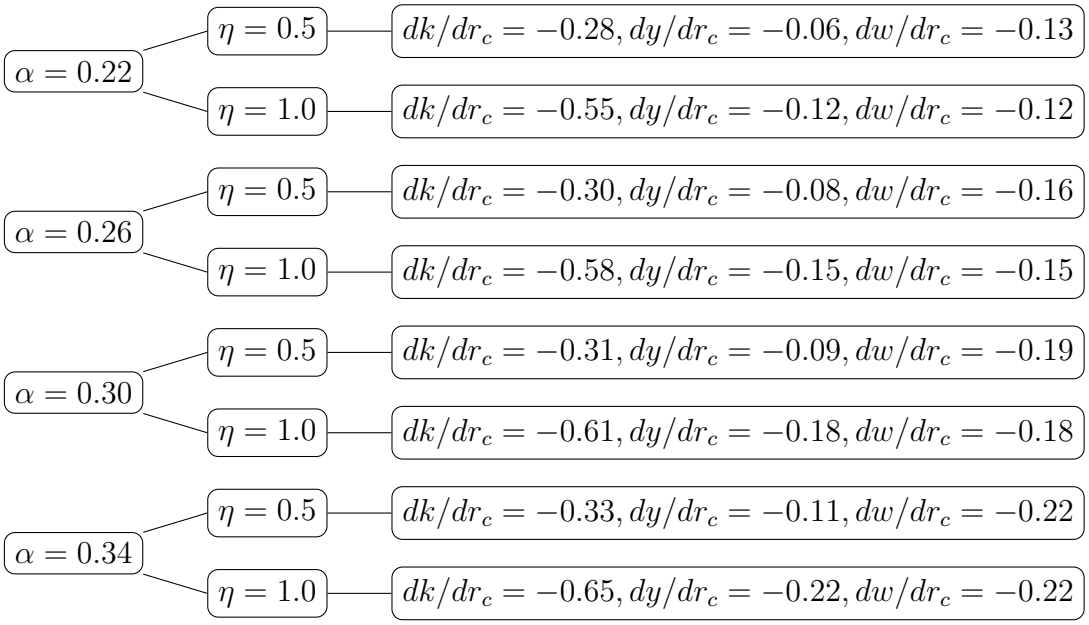
$$\frac{d\ell_c}{dr_c} = \frac{d\ell_n}{dr_c} + \eta\left(\frac{\alpha\eta\xi}{(\alpha+\beta)\,\eta\xi - 1}\right), \tag{52e}$$

$$\frac{dy_i}{dr_c} = \alpha\frac{dk_i}{dr_c} + \beta\frac{d\ell_i}{dr_c}. \tag{52f}$$

Figure 4 repeats Figure 3 in the economy with two sectors, starting from initial symmetry. The presence of the non C-corporate sector without a tax change makes the responses of C-corporate capital and output larger, as the sector can pull in labor. This response is offset however by the decline in the non C-corporate sector. Locally, the responses of aggregate capital, labor, and the wage simply scale their counterparts in Figure 3 by the factor 0.43 of initial activity in the corporate sector.[33] For example, the elasticity of the wage to the C-corporate user cost is in the range of -0.1 to -0.2.

[33] With *ex ante* differences, there would be additional gains or losses from the reallocation of activity. The scaling also only applies locally; in the limit with constant returns to scale, the C-corporate sector would immediately take over the whole economy after a tax cut and Figure 3 would apply with no scaling factor.

Figure 4: General Equilibrium Elasticities with Two Sectors



Notes: Each "tree" starts from a value for the revenue elasticity of capital α. The "branches" set the elasticity of substitution between capital and labor η. The "leaves" give the implied values for the long-run general equilibrium user cost elasticity of corporate capital, corporate value added, and the wage. In all branches the markup is set to $\mathcal{M} = 1$ and the share of labor in the C-corporate sector is set to $\omega_c = 0.43$.

5.3 The General Equilibrium Tax-term Elasticity in the Neoclassical Model

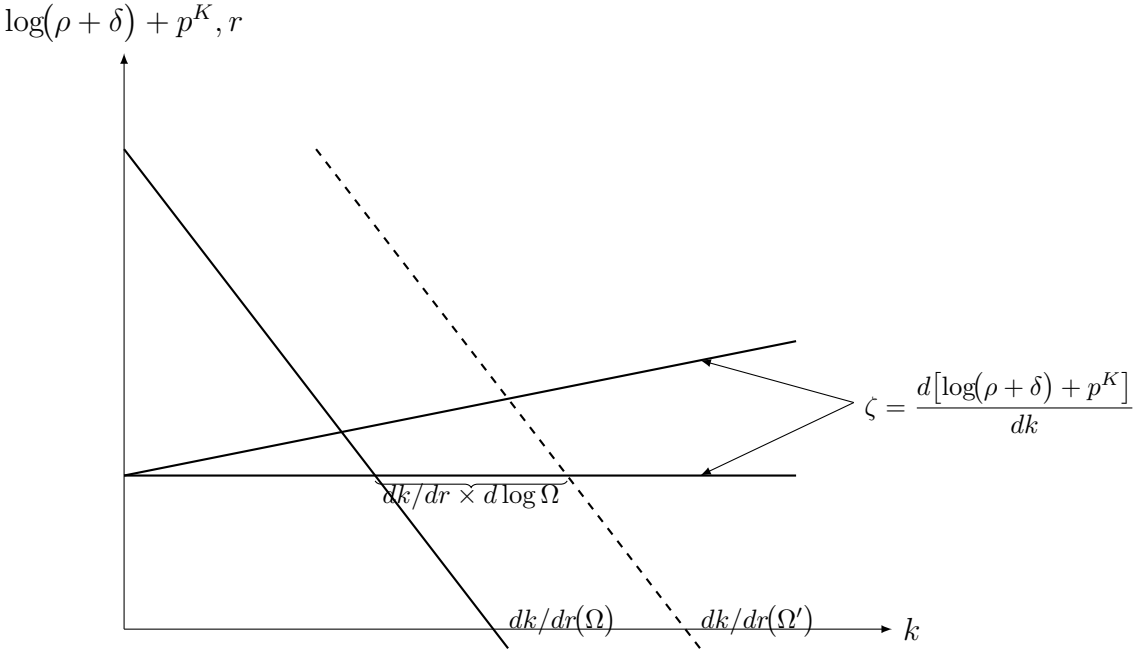
The general equilibrium elasticities summarized in Figures 3 and 4 apply to changes in the user cost. As a result, they apply holding fixed the non-tax component $(\rho + \delta)P^K$ when the tax term $\Omega \equiv (1 - \Gamma)/(1 - \tau)$ changes. However, the non-tax component could change endogenously, due to crowd-out from an upward-sloping savings curve that makes ρ a function of K or an upward-sloping capital supply curve that makes P^K a function of K. Let $\zeta \equiv d\left[\log(\rho + \delta) + p^K\right]/dk$ denote the inverse supply elasticity.

Figure 5 summarizes the equilibrium inclusive of any changes to the non-tax component of the user cost. The vertical axis is the log of the non-tax component. The downward sloping lines have slope dk/dr. A decline from Ω to $\Omega' < \Omega$ shifts the schedule to the right by the amount $dk/dr \times d\log\Omega$. With $\zeta = 0$, this shift gives the total effect of the tax change. With $\zeta > 0$,

$dk/d\log\Omega$ is reduced. Algebraically, the equilibrium is the solution to the system of equations:

$$\begin{aligned}
&\text{Capital demand:} && dk = (dk/dr)\, d\left[\log(\rho+\delta) + p^K + \log\Omega\right], \\
&\text{Capital supply:} && d\left[\log(\rho+\delta) + p^K\right] = \zeta dk, \\
&\text{Equilibrium:} && dk = \frac{dk/dr}{1-\zeta\,(dk/dr)} d\log\Omega.
\end{aligned}$$

Figure 5: General Equilibrium Tax Elasticity



The total general equilibrium capital elasticity to a tax change therefore combines dk/dr found in Figure 3 or Figure 4 with a value for ζ. In an infinite horizon Ramsey economy or a small open economy facing a world interest rate, the interest rate ρ does not depend on investment. Moll, Rachel and Restrepo (2022) suggest a semi-elasticity of savings to the interest rate of 50, implying $\zeta = 1/(\rho+\delta) \times 1/50 = 0.125$ using $\rho+\delta = 0.16$ and $P^K = 1$. This value provides an upper bound for the response to corporate tax changes, since corporate capital is only about 40% of the total capital stock. Goolsbee (1998) finds a large response of capital goods prices to tax incentives. House and Shapiro (2008) and House, Mocanu and Shapiro (2022) dispute this conclusion, with House, Mocanu and Shapiro (2022) finding that the Goolsbee (1998) result disappears with revised data or in longer samples and arguing instead that $dp^K/dk \approx 0$.

5.4 The General Equilibrium Elasticity of Tax Revenue in the Neoclassical Model

Steady state corporate tax payments are $\tau (Y - WL) - \Gamma I$.[34] Adding labor tax payments with a tax rate τ^L, setting $I = \delta K$, and using the labor first order condition (6a), total taxes T are:

$$T = \overbrace{\tau \left(A \left(F \left(K, L \right) - F_L \left(K, L \right) L \right) - \delta z K \right)}^{\text{Corporate taxes} \equiv CT} + \overbrace{\tau^L A F_L \left(K, L \right) L}^{\text{Labor taxes} \equiv LT}. \tag{53}$$

Let CT and LT denote corporate taxes and labor taxes, respectively. Start with changes in the corporate rate τ. It is convenient to express taxes paid as a share of baseline corporate revenue Y. For notational simplicity, let $\mathcal{M} = 1$. The semi-elasticities of corporate, labor, and total taxes to the corporate tax rate are (see equations (A.14) and (A.15)):

$$\frac{1}{Y} \times \frac{dCT}{d \log \tau} = \frac{CT}{Y} + c_{CT} \frac{dk}{d \log \tau}, \text{ where: } c_{CT} \equiv \tau \left(\alpha^* \left(1 - \beta^* \right) - \frac{\partial \beta^*}{\partial k} - \frac{z \delta K}{Y} \right), \tag{54a}$$

$$\frac{1}{Y} \times \frac{dLT}{d \log \tau} = c_{LT} \frac{dk}{d \log \tau}, \text{ where: } c_{LT} \equiv \tau^L \left(\alpha^* \beta^* + \frac{\partial \beta^*}{\partial k} \right), \tag{54b}$$

$$\frac{1}{Y} \times \frac{dT}{d \log \tau} = \frac{CT}{Y} + \left(c_{CT} + c_{LT} \right) \frac{dk}{d \log \tau}, \tag{54c}$$

and where $\partial \beta^* / \partial k = \left(\frac{1 - \eta}{(\alpha + \beta) \eta} \right) \alpha^* \beta^*$ denotes the semi-elasticity of the labor share of revenue to a change in capital, holding labor fixed (see equation (A.11)).

The first term in equation (54c), CT/Y, gives the mechanical effect of a change in the tax rate holding the corporate and labor tax bases fixed. The coefficients c_{CT} and c_{LT} give the feedback from additional capital to corporate and labor taxes, respectively. The change in the corporate tax base when capital increases equals the change in output, $\alpha^* dk$, multiplied by the share of output accruing to owners of capital, $(1 - \beta^*)$, less the change in the labor share when capital increases, $\partial \beta^* / \partial k \times dk$, less the additional depreciation deductions $z \delta dK$. The change in the labor tax base equals the change in output multiplied by the labor share, $\beta^* \alpha^* dk$, plus the change in the labor share. The coefficients c_{CT} and c_{LT} multiply the changes in the corporate and labor tax bases by their respective marginal tax rates. These coefficients therefore also apply to dynamic changes in capital induced by changes in z, while the mechanical effect in that case is instead the tax rate

[34] To streamline the analysis, this sub-section assumes uniform taxation of all business income, which with abuse of terminology I refer to as the corporate tax system. In the notation of Section 5.2, $\tau_c = \tau_n = \tau$ and $z_c = z_n = z$. It also ignores payout taxes (e.g. dividend taxes) and the transition path. See Chodorow-Reich et al. (2025) for a quantitative evaluation of TCJA incorporating these features.

applied to steady state investment $-\tau I/Y$:

$$\frac{1}{Y} \times \frac{dT}{dz} = -\frac{\tau I}{Y} + (c_{CT} + c_{LT}) \frac{dk}{dz}. \tag{55}$$

In 2024, corporate taxes equaled roughly 4% of corporate value added, $CT/Y \approx 0.04$ (U.S. Bureau of Economic Analysis, 2025*b*). This value has remained remarkably stable since the 1980s, as a rising corporate profit share has offset a declining tax rate. Thus, the mechanical reduction in revenue from a 10% decline in the corporate tax rate is roughly 0.4% of corporate value added. For $\tau = 0.18$, $z = 0.85$, $\tau^L = 0.28$ (all approximately values for the average U.S. firm or worker in 2024), and values of α between 0.22 and 0.34 and $\eta \in \{0.5, 1\}$, the dynamic component $(c_{CT} + c_{LT})\, dk/d\log\tau$ offsets less than 10% of the mechanical decline in revenue (see Figure A.1). Alternatively, this range of parameter values implies a dynamic offset of between 25% and 45% of the mechanical revenue decline when z increases.

The result that the dynamic growth effects of corporate tax cuts do not outweigh the mechanical revenue losses reflects the current, relatively low tax corporate regime in the U.S. Higher values of τ or, especially, lower values of z could alter this conclusion. Several other caveats apply: these neoclassical formulas do not take account of international capital mobility and profit shifting, changes in corporate form in response to tax changes, or differences in the discounting of future depreciation allowances by firms and the government. They also do not incorporate higher interest payments if the interest rate increases (see Section 5.3), which may be non-trivial when the debt-GDP ratio is large.

5.5 Existing Policy Approaches

Major policy institutions routinely provide estimates of the effects of changes to corporate taxation on capital and output. I close this section by reviewing these approaches, in order to provide context for the merits and demerits of the neoclassical approach.

Council of Economic Advisers (2019, 2025) follow Hall and Jorgenson (1967). Council of Economic Advisers (2019, p. 68) describes their method:

> Calculations yield an estimated decline in the average user cost of capital of about 9 percent. Assuming a consensus user-cost elasticity of investment of -1.0, a 9 percent decline in the average user cost of capital would induce a 9 percent increase in the demand for capital. Following Jensen, Mathur, and Kallen (2017), it is then possible to use the Multifactor Productivity Tables from the Bureau of Labor Statistics in a growth accounting framework to increment the Congressional Budget Office's

10-year GDP growth projections by the additional contribution to output from a larger capital stock, assuming constant capital income shares, until we attain a new steady state.

This approach differs in three important ways from the analysis above. First, it follows Hall and Jorgenson (1967) in applying the "neoclassical benchmark" elasticity of -1.0 without allowing for feedback from higher output back into higher capital.[35] Second, the "consensus user-cost elasticity" of -1 differs from my preferred range and relies in part on studies such as Dwenger (2014) that estimate the Eisner and Nadiri (1968) specification.[36] Third, it does not explicitly account for the non C-corporate sector.

Congressional Research Service (2024, pp. 16-17) likewise follows the Hall and Jorgenson (1967) approach of omitting feedback from higher output into higher capital. They apply an elasticity of 0.6 based on an average of Dwenger (2014) and a comparable study finding a smaller Eisner and Nadiri (1968) elasticity. Thus, both Council of Economic Advisers (2019, 2025) and Congressional Research Service (2024) use smaller elasticities for aggregate capital than found in Figure 3 in part because they take only the first step of the cobweb adjustment process, as originally critiqued by Coen (1969).

The Congressional Budget Office (CBO) first applies an aggregate Eisner and Nadiri (1968) investment elasticity of -0.7 to a user cost change holding output fixed (Congressional Budget Office, 2018*a*,*b*). The value of -0.7 comes from CBO's own analysis and is compared to the Hassett and Hubbard (2002) range of -0.5 to -0.1 (Congressional Budget Office, 2018*b*, p. 3), despite that range coming from studies mostly estimating the Coen (1969) specification across firms and at short horizons. CBO then inputs the change in investment into its macroeconomic model featuring feedback from output into investment as well as crowding out due to higher interest rates and inelastic labor (using an elasticity of labor supply of 0.2).[37]

[35]The phrase "until we attain a new steady state" may seem to imply such iteration, but it does not. Jensen, Mathur and Kallen (2017) link to a spreadsheet that fully documents the method. Starting from a baseline path of investment from 2017 forward, investment in each year is increased by 9% relative to the baseline path. This alternative path of investment implies an alternative path of capital using the perpetual inventory relationship $K_{t+1} = (1 - \delta) K_t + I_t$. Multiplying the additional capital by the capital-income share gives the increase in GDP in each year.

[36]See the literature review in Council of Economic Advisers (2019, p. 58). In addition, Council of Economic Advisers (2019, p. 58) refers to Cummins, Hassett and Hubbard (1994, 1996) as finding "an estimated long-run elasticity of the capital stock of -0.67", despite these articles using short-run variation. See Table 2 and Figure 2 for my re-analysis of these studies.

[37]The CBO macroeconomic model combines a short run with demand-determined output with a long-run Solow-type growth model. In the short run, higher investment boosts demand and causes GDP to increase relative to

The CBO method offers an especially useful contrast to the neoclassical approach. Their mandate requires obtaining a transition path incorporating aggregate demand forces not present in a neoclassical setting. Furthermore, evaluating macroeconomic effects using a common framework facilitates comparisons with evaluations of other policy changes. At the same time, the complexity of the CBO method comes at the cost of computational transparency; because CBO also evaluates several policies together, no easy quantitative comparison exists between the long-run effects of a tax policy change in CBO and the numbers reported in Figure 3.

6 Conclusion

Some of the most exciting current work in firm-level dynamics incorporates rich heterogeneity in production technology, product differentiation, and market size. How firms respond to changes in the cost of investment or taxation of profits can provide key moments to discipline these models (Koby and Wolf, 2020). The empirical literature has focused on tax reforms as a particular good laboratory to measure these responses. These episodes also offer direct evidence to policy makers considering further changes to corporate taxation.

The interpretation of this body of empirical work requires properly relating the empirical moments to theory parameters. As frequently occurs in macroeconomics, such structural interpretation has particular import in settings such as tax policy where the difficulty of assigning causality in the time series and the infrequent nature of tax reforms lead empiricists away from directly estimating the key objects of interest to policy makers, in this case the long-run effect on aggregate capital and wages of an aggregate tax policy change.

In this paper I have attempted to re-connect the modern empirical literature studying firm-level responses to tax reforms to the neoclassical theory of investment. The variety of empirical specifications and looseness of terminology have sometimes hampered this endeavor, resulting in improper comparisons across studies. After accounting for these differences, I find a range for the short-run semi-elasticity of the investment-to-capital ratio to the user cost of -0.2 to below -1, with most values in the more compact range of -0.25 to -0.75. The mid-point of this range implies a revenue elasticity of capital of 0.22 to 0.35 and total returns to scale in the firm's revenue function

potential. In the long run, higher output increases aggregate savings which then results in even higher capital, similar to the cobweb adjustment process described in Section 2.3.

of 0.87 or above. In general equilibrium, the aggregate long-run elasticity of capital to its user cost consistent with the short-run cross-firm evidence ranges from -1.3 to -1.7 with Cobb-Douglas and otherwise roughly scales from there with the elasticity of substitution between capital and labor. The elasticity of the wage to the user cost ranges from -0.3 to -0.7. These elasticities all scale by a factor of about 0.4 for changes to the user cost in the C-corporate sector alone.

My analysis has remained squarely inside the conventional neoclassical theory of the firm facing convex adjustment costs of capital. Recent work has increasingly enriched this framework, including estimation of the extensive margin of adjustment (Chen et al., 2023), substitution elasticities with multiple types of labor (Curtis et al., 2021), and extending the framework to include intangibles (Crouzet and Eberly, 2023) or a multinational setting (Chodorow-Reich et al., 2025). The framework given here may provide a benchmark for comparing to these papers as well.

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Online Appendix: The Neoclassical Theory of Investment and Taxes

Gabriel Chodorow-Reich

Table A.1: Notation Summary

Symbol	Definition	Description	Eq.
$K_{i,t}$		Firm capital input	
$L_{i,t}$		Firm labor input	
$Y_{i,t}$	$A_{i,t}F\left(K_{i,t}, L_{i,t}\right)$	Firm revenue	(1)
$I_{i,t}$	$\dot{K}_{i,t} + \delta K_{i,t}$	Gross investment	(2)
$z_{i,t}$		Present value of depreciation allowances	(4)
$\tau_{i,t}$		Corporate tax rate	
$\Gamma_{i,t}$	$itc_{i,t} + \tau_{i,t} z_{i,t}$	Effective subsidy to cost of new investment	(3)
ρ		Discount rate	
δ		Depreciation rate	
P_t^K		Common price of new investment	
W_t		Common wage	
$\lambda_{i,t}$		Marginal value of unit of capital	(7)
R_i	$(\rho + \delta) P^K \left(\frac{1-\Gamma_i}{1-\tau_i}\right)$	Steady state user cost	(9)
$\Omega_{i,t}$	$\frac{1-\Gamma_{i,t}}{1-\tau_{i,t}}$	Tax term	(10)
α		Cobb Douglas elasticity of revenue to capital	(11)
β		Cobb Douglas elasticity of revenue to labor	(11)
γ	$\alpha/(1-\beta)$	Cobb Douglas elasticity of revenue to capital allowing labor to adjust	(17)
η		Elasticity of substitution between capital and labor	(20)
α_i^*	$R_i K_i / Y_i$	Steady state capital share of revenue	
β_i^*	$W L_i / Y_i$	Steady state labor share of revenue	
ϕ		Scalar in quadratic adjustment costs	(26)
$Q_{i,t}$	$\frac{\lambda_{i,t} - P_t^K(1-\Gamma_{i,t})}{1-\tau_{i,t}}$	Transformation of Brainard-Tobin's q	(28)
$G_{i,t}\left(K_{i,t}\right)$	$\max_{L_{i,t}} A_{i,t}F\left(K_{i,t}, L_{i,t}\right) - W_t L_{i,t}$	Revenue net of labor costs	(29)
χ_i	$\frac{\rho}{2} - \sqrt{\left(\frac{\rho}{2}\right)^2 - \frac{G_i''(K_i)K_i}{\phi}}$	Stable eigenvalue	(33)
$b_1^{\text{Coen}k,r}$	dk_i/dr_i	Long-run firm-level Coen (1969) elasticity of capital to user cost	(40a)
$\mathcal{M}$		Equilibrium markup	
ζ	$d\left[\log\left(\rho+\delta\right) + p^K\right]/dk$	Inverse supply elasticity	

A Theory Appendix

This appendix provides additional results used in Sections 2 and 5. Table A.1 summarizes key notation used throughout the paper. In addition, lower case variables denote logs, variables or parameters with an i subscript pertain to the firm-level, and variables without an i pertain to the aggregate economy.

A.1 Additional CES Derivations

This appendix expands on results in Section 2.4. Using equations (21a) and (21b) and the necessary conditions equations (6a) and (9), the total cost share of revenue is:

$$\begin{aligned}\frac{R_iK_i+W_iL_i}{Y_i} &= \frac{F_K\left(K_i,L_i\right)K_i+F_L\left(K_i,L_i\right)L_i}{F\left(K_i,L_i\right)} = \frac{\alpha F\left(K_i,L_i\right)^{1+\frac{1-\eta}{(\alpha+\beta)\eta}}K_i^{1-\frac{1}{\eta}}+\beta F\left(K_i,L_i\right)^{1+\frac{1-\eta}{(\alpha+\beta)\eta}}L_i^{1-\frac{1}{\eta}}}{F\left(K_i,L_i\right)} \\ &= \alpha F\left(K_i,L_i\right)^{\frac{1-\eta}{(\alpha+\beta)\eta}}K_i^{1-\frac{1}{\eta}}+\beta F\left(K_i,L_i\right)^{\frac{1-\eta}{(\alpha+\beta)\eta}}L_i^{1-\frac{1}{\eta}} \\ &= \frac{\alpha K_i^{1-\frac{1}{\eta}}+\beta L_i^{1-\frac{1}{\eta}}}{\left(\frac{\alpha}{\alpha+\beta}\right)K_i^{1-1/\eta}+\left(\frac{\beta}{\alpha+\beta}\right)L_i^{1-1/\eta}} = \alpha+\beta. \end{aligned} \tag{A.1}$$

In the partial equilibrium Coen (1969) elasticity, the wage remains fixed. Then substituting equation (21b) into equation (6a), log differentiating, and setting $dw = 0$:

$$d\ell_i = \left(\eta+\frac{1-\eta}{(\alpha+\beta)}\right)dy_i = \left(\eta+\frac{1-\eta}{(\alpha+\beta)}\right)\left(\alpha_i^*dk_i+\beta_i^*d\ell_i\right) = \frac{\left(\eta+\frac{1-\eta}{(\alpha+\beta)}\right)\alpha_i^*}{1-\left(\eta+\frac{1-\eta}{(\alpha+\beta)}\right)\beta_i^*}dk_i. \tag{A.2}$$

Substitute $\frac{\partial y_i}{\partial k_i} = \frac{\alpha_i^*}{1-\left(\eta+\frac{1-\eta}{\alpha+\beta}\right)\beta_i^*}$ from equation (A.2) into equation (24):

$$\begin{aligned}\frac{dk_i}{dr_i} &= \left(\left(\frac{\left(1+\frac{1-\eta}{(\alpha+\beta)\eta}\right)\alpha_i^*}{1-\left(\eta+\frac{1-\eta}{\alpha+\beta}\right)\beta_i^*}\right)-\frac{1}{\eta}\right)^{-1} = \left(\frac{1-\left(\eta+\frac{1-\eta}{\alpha+\beta}\right)\beta_i^*}{\left(1+\frac{1-\eta}{(\alpha+\beta)\eta}\right)\alpha_i^*-\frac{1}{\eta}\left(1-\left(\eta+\frac{1-\eta}{\alpha+\beta}\right)\beta_i^*\right)}\right) \\ &= -\left(\frac{1-\beta_i^*\left(\eta+\frac{1-\eta}{\alpha+\beta}\right)}{1-\alpha-\beta}\right). \end{aligned} \tag{A.3}$$

A.2 Linearized Transition Path

This appendix expands on results in Section 2.6. The Taylor expansion uses the result that $\Phi_K\left(I_{i,t},K_{i,t}\right)=0$ in the steady state and hence $d\Phi_K\left(I_{i,t},K_{i,t}\right) = -\phi\delta d\dot{K}_{i,t}/K_{i,t} = -\delta/\left(1-\tau_i\right)\left(\lambda_{i,t}-\lambda_i\right)$. Restating equation (31) for convenience:

$$\begin{pmatrix}\dot{\lambda}_{i,t}\\ \dot{K}_{i,t}\end{pmatrix} = \begin{pmatrix}\rho & -\left(1-\tau_i\right)G_i''\left(K_i\right)\\ K_i/\left(\phi\left(1-\tau_i\right)\right) & 0\end{pmatrix}\begin{pmatrix}\lambda_{i,t}-\lambda_i\\ K_{i,t}-K_i\end{pmatrix}$$

Let $\mathbf{A}$ denote the coefficient matrix in equation (31). Denote by $(\chi_1,\mathbf{f}_1)$ and $(\chi_2,\mathbf{f}_2)$ the eigenvalue/eigenvector pairs of $-\mathbf{A}$, with:

$$\chi_1 = \frac{\rho}{2}-\sqrt{\left(\frac{\rho}{2}\right)^2-\frac{G_i''\left(K_i\right)K_i}{\phi}} < 0, \chi_2 = \frac{\rho}{2}+\sqrt{\left(\frac{\rho}{2}\right)^2-\frac{G_i''\left(K_i\right)K_i}{\phi}} > 0, \tag{A.4}$$

$$\mathbf{f}_1 = \begin{pmatrix}\chi_1 & K_i/\left(\left(1-\tau_i\right)\phi\right)\end{pmatrix}', \mathbf{f}_2 = \begin{pmatrix}\chi_2 & K_i/\left(\left(1-\tau_i\right)\phi\right)\end{pmatrix}'. \tag{A.5}$$

The general solution is:

$$\begin{pmatrix}\lambda_{i,t}-\lambda_i\\ K_{i,t}-K_i\end{pmatrix} = c_1e^{\chi_1 t}\mathbf{f}_1+c_2e^{\chi_2 t}\mathbf{f}_2.$$

Immediately, $G'' < 0 \Rightarrow \chi_2 > \rho$, which requires $c_2 = 0$ or the transversality condition would be violated. Thus:

$$\begin{pmatrix} \lambda_{i,t} - \lambda_i \\ K_{i,t} - K_i \end{pmatrix} = c_1 e^{\chi_1 t} \begin{pmatrix} \chi_1 \\ K_i / \left((1 - \tau_i)\, \phi \right) \end{pmatrix}. \tag{A.6}$$

The initial condition $K_{i,0}$ gives:

$$c_1 = \left(\frac{K_{i,0} - K_i}{K_i} \right) (1 - \tau_i)\, \phi. \tag{A.7}$$

Then defining $\chi_i \equiv \chi_1$ and using the approximation $k_{i,t} - k_i \approx (K_{i,t} - K_i)/K_i$ gives equations (33), (32a) and (32b) in the main text.

A.3 2 Sector General Equilibrium

This appendix expands on results in Section 5.2. I restate equations (51a) to (51d) for convenience:

$$\begin{aligned} dw &= \xi dy_i - \frac{1}{\eta} d\ell_i, \;\; i \in \{c, n\}, \\ dr_i &= \xi dy_i - \frac{1}{\eta} dk_i, \;\; i \in \{c, n\}, \\ dy_i &= \alpha dk_i + \beta d\ell_i, \;\; i \in \{c, n\}, \\ d\ell_c &= - \left(\frac{1 - \omega_c}{\omega_c} \right) d\ell_n. \end{aligned}$$

Using equation (51c),

$$d\ell_i = \frac{dy_i - \alpha dk_i}{\beta}.$$

Substitute into equation (51a):

$$\begin{aligned} dw &= \xi dy_i - \frac{dy_i - \alpha dk_i}{\beta \eta}, \\ dk_i &= \frac{\beta \eta}{\alpha} \left(dw - \left(\xi - \frac{1}{\beta \eta} \right) dy_i \right). \end{aligned}$$

Rewrite equation (51b) as $dy_i = \left(\frac{1}{\eta} dk_i + dr_i \right) / \xi$ and substitute:

$$\begin{aligned} dk_i &= \frac{\beta \eta}{\alpha} \left(dw - \left(\xi - \frac{1}{\beta \eta} \right) \frac{1}{\xi} \left(\frac{1}{\eta} dk_i + dr_i \right) \right) \\ &= \beta \eta \left(\frac{\eta \xi}{(\alpha + \beta)\, \eta \xi - 1} \right) \left(dw - \left(1 - \frac{1}{\beta \eta \xi} \right) dr_i \right). \end{aligned} \tag{A.8}$$

Next solve for labor as a function of prices using equations (51a) and (51b) to write $d\ell_i = -\eta \left(dw - dr_i \right) + dk_i$:

$$\begin{aligned} d\ell_i &= -\eta \left(dw - dr_i \right) + \beta \eta \left(\frac{\eta \xi}{(\alpha + \beta)\, \eta \xi - 1} \right) \left(dw - \left(1 - \frac{1}{\beta \eta \xi} \right) dr_i \right) \\ &= \eta \left(\frac{1 - \alpha \eta \xi}{(\alpha + \beta)\, \eta \xi - 1} \right) dw + \eta \left(\frac{\alpha \eta \xi}{(\alpha + \beta)\, \eta \xi - 1} \right) dr_i. \end{aligned} \tag{A.9}$$

Using equation (A.9) for sector n and equation (51d):

$$d\ell_c = -\left(\frac{1-\omega_c}{\omega_c}\right)\left(\eta\left(\frac{1-\alpha\eta\xi}{(\alpha+\beta)\eta\xi-1}\right)dw + \eta\left(\frac{\alpha\eta\xi}{(\alpha+\beta)\eta\xi-1}\right)dr_n\right).$$

Equate with equation (A.9) for sector c and solve for w:

$$dw = -\left(\frac{\alpha\eta\xi}{1-\alpha\eta\xi}\right)\left(\omega_c dr_c + (1-\omega_c)\,dr_n\right). \tag{A.10}$$

A.4 Tax Revenue

This appendix expands on results in Section 5.4. The derivation makes use of two preliminary calculations related to the CES production function. First, the partial (holding labor fixed) semi-elasticity of the labor share of revenue to capital is:

$$\frac{\partial\beta^*}{\partial k} = \left(\frac{1-\eta}{(\alpha+\beta)\eta}\right)\alpha^*\beta^*. \tag{A.11}$$

This result uses:

$$\beta^* = \frac{F_L(K_{i,t},L_{i,t})L_{i,t}}{F(K_{i,t},L_{i,t})} = \beta F(K_{i,t},L_{i,t})^{\frac{1-\eta}{(\alpha+\beta)\eta}}L_{i,t}^{1-1/\eta} = \frac{\beta}{\left(\frac{\alpha}{\alpha+\beta}\right)(K_{i,t}/L_{i,t})^{1-1/\eta}+\left(\frac{\beta}{\alpha+\beta}\right)},$$

$$\alpha^* = \frac{F_K(K_{i,t},L_{i,t})K_{i,t}}{F(K_{i,t},L_{i,t})} = \alpha F(K_{i,t},L_{i,t})^{\frac{1-\eta}{(\alpha+\beta)\eta}}K_{i,t}^{1-1/\eta} = \frac{\alpha}{\left(\frac{\alpha}{\alpha+\beta}\right)+\left(\frac{\beta}{\alpha+\beta}\right)(K_{i,t}/L_{i,t})^{1/\eta-1}}.$$

Second, the cross-partial of the CES production function is:

$$\begin{aligned}F_{LK}(K_{i,t},L_{i,t}) &= \left(1+\frac{1-\eta}{(\alpha+\beta)\eta}\right)\beta F(K_{i,t},L_{i,t})^{\frac{1-\eta}{(\alpha+\beta)\eta}}L_{i,t}^{-\frac{1}{\eta}}F_K(K_{i,t},L_{i,t})\\ &= \left(1+\frac{1-\eta}{(\alpha+\beta)\eta}\right)\frac{F_K(K_{i,t},L_{i,t})F_L(K_{i,t},L_{i,t})}{F(K_{i,t},L_{i,t})}.\end{aligned}$$

Using the first order conditions (6a) and (9) and equation (A.11), in steady state this becomes:

$$\frac{A_i F_{LK}(K_i,L_i)K_iL_i}{Y_i} = \left(1+\frac{1-\eta}{(\alpha+\beta)\eta}\right)\alpha^*\beta^* = \alpha^*\beta^* + \frac{\partial\beta^*}{\partial k}. \tag{A.12}$$

Change in τ Let $CTB = CT/\tau$ denote the corporate tax base:

$$CTB = A(F(K,L) - F_L(K,L)L) - \delta z K.$$

The change in corporate taxes in response to a 1% change in the corporate tax rate, expressed as a share of baseline total corporate value-added, is:

$$\begin{aligned}\frac{1}{Y}\times\frac{dCT}{d\log\tau} &= \left(\frac{CT}{Y}\right)\frac{d\log CT}{d\log\tau} \qquad (A.13)\\ &= \left(\frac{CT}{Y}\right)\left(1+\frac{d\log CTB}{d\log\tau}\right)\\ &= \left(\frac{CT}{Y}\right)\left(1+\frac{1}{CTB}\left(A\left(F_K\left(K,L\right)-F_{KL}\left(K,L\right)L\right)-\delta z\right)\frac{dK}{d\log\tau}\right)\\ &= \left(\frac{CT}{Y}\right)\left(1+\frac{1}{CTB}\left(A\left(F_K\left(K,L\right)K-F_{KL}\left(K,L\right)KL\right)-\delta zK\right)\frac{dk}{d\log\tau}\right)\\ &= \frac{CT}{Y}+\tau\left(\alpha^*\left(1-\beta^*\right)-\frac{\partial\beta^*}{\partial k}-\frac{zI}{Y}\right)\frac{dk}{d\log\tau}. \qquad (A.14)\end{aligned}$$

The change in labor taxes is:

$$\begin{aligned}\frac{1}{Y}\times\frac{dLT}{d\log\tau} &= \frac{\tau^L AF_{KL}\left(K,L\right)L}{Y}\frac{dK}{d\log\tau}\\ &= \frac{\tau^L AF_{KL}\left(K,L\right)KL}{Y}\frac{dk}{d\log\tau}\\ &= \tau^L\left(\alpha^*\beta^*+\frac{\partial\beta^*}{\partial k}\right)\frac{dk}{d\log\tau}. \qquad (A.15)\end{aligned}$$

Change in z We have:

$$\begin{aligned}\frac{1}{Y}\times\frac{dCT}{dz} &= \left(\frac{\tau}{Y}\right)\frac{d}{dz}\left[A\left(F\left(K,L\right)-F_L\left(K,L\right)L\right)-\delta zK\right]\\ &= \left(\frac{\tau}{Y}\right)\left(\left(A\left(F_K\left(K,L\right)K-F_{KL}\left(K,L\right)KL\right)-\delta zK\right)\frac{dk}{dz}-\delta K\right)\\ &= -\frac{\tau I}{Y}+\tau\left(\alpha^*\left(1-\beta^*\right)-\frac{\partial\beta^*}{\partial k}-\frac{zI}{Y}\right)\frac{dk}{dz}.\end{aligned}$$

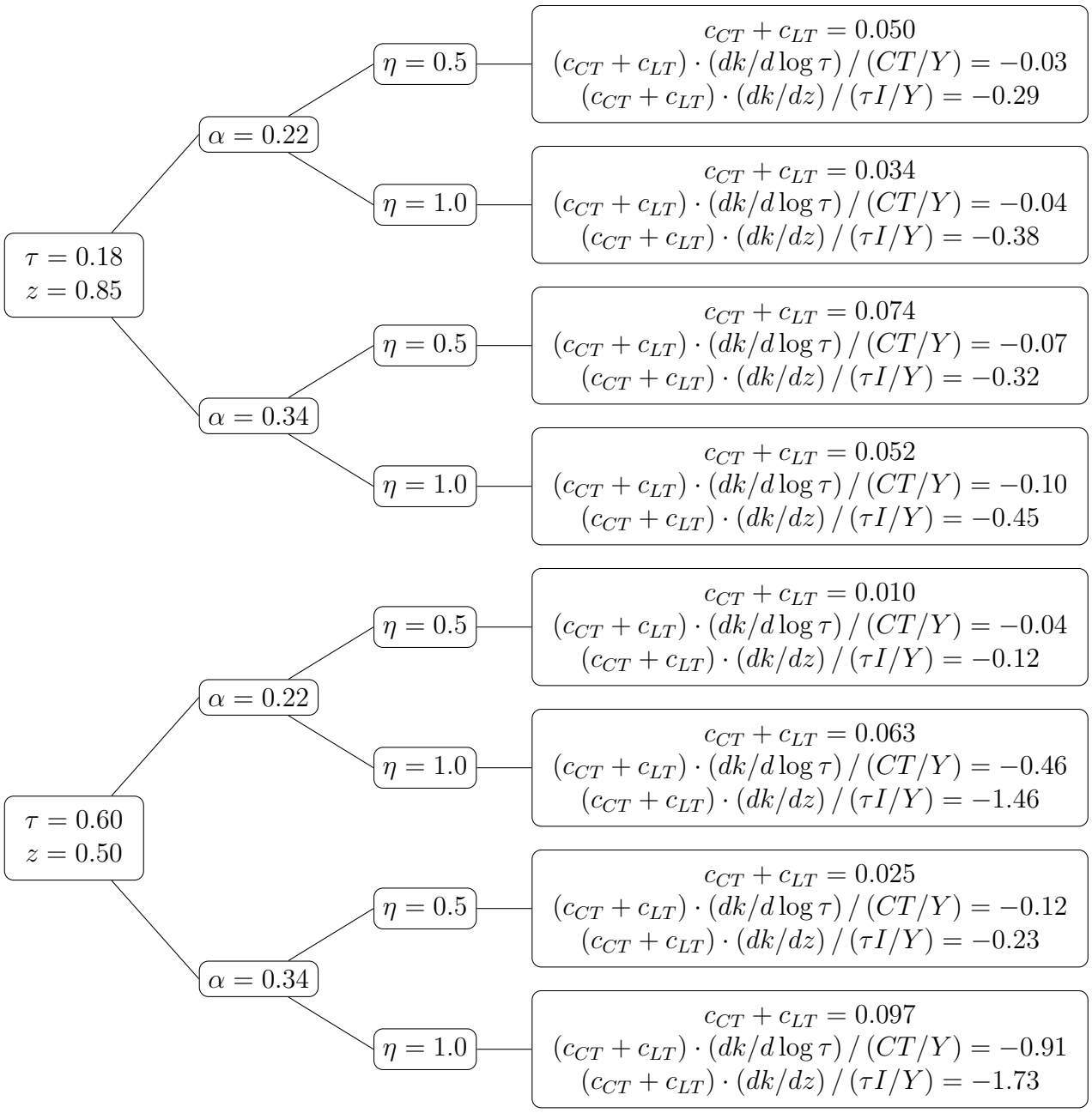
Thus, while the mechanical effect of a change in z differs from the mechanical effect of a change in $\log\tau$, the dynamic coefficient for corporate taxes is the same. The dynamic coefficient for labor taxes is likewise the same.

Figure A.1 shows values for the ratio of the dynamic to mechanical revenue change for different policy instruments and parameters. The top tree uses values of τ and z approximately equal to those in the U.S. in 2024. The bottom tree shows that with higher baseline tax rates, larger dynamic revenue effects are possible.

B Additional Notes on the Literature

This appendix contains additional notes on the papers listed in Tables 1 to 4.

Figure A.1: General Equilibrium Dynamic Tax Responses



Notes: Each "tree" starts from a value for the corporate rate τ and present value of expensing z. The "branches" set the capital output elasticity α and elasticity of substitution between capital and labor η. The "leaves" give the implied values for the long-run general equilibrium dynamic tax coefficient and the ratio of the dynamic to mechanical revenue change. All trees and branches use $\tau^L = 0.28$ and $\mathcal{M} = 1$.

Auerbach and Hassett (1991) They do not report summary statistics for the value of the user cost. For the non tax component, they use a discount rate $\rho = 0.04$ (p. 203). Using their table 1, I calculate an asset-weighted average depreciation rate for equipment of $\delta = 0.15$, where the asset weights come from assuming 1985 investment is equal to the replacement level of investment. For the tax component, Cummins, Hassett and Hubbard (1994, figure 1) implies a value $\Omega = 1.17$ for equipment in 1985. Together, this gives an average user cost for equipment $R = (\rho + \delta)\Omega = 0.226$. Note that this is close to the value of 0.25 reported in Cummins, Hassett and Hubbard (1994) for their full sample.

Cummins, Hassett and Hubbard (1994) I include their results for major tax reform years.

Zwick and Mahon (2017) I report their specification using $\log I$ because it is their preferred outcome and the only outcome for which they report results separately by firm size.

Curtis et al. (2021) This paper regresses the long-difference in equipment capital on an indicator for a firm's no-bonus z, denoted z_N, being in the bottom tercile of the distribution. The change in z given a value of bonus of B is $B + (1 - B)\, z_N - z_N = B\,(1 - z_N)$. Thus, the mean difference-in-difference change in z across the "treated" and "control" firms is $B \times (\mathbb{E}_i[z_{i,N} | z_{i,N} \leq P_{33}(z_N)] - \mathbb{E}_i[z_{i,N} | z_{i,N} > P_{33}(z_N)])$. In the main text I use the difference-in-difference notation $\Delta_{2001,2011}\Delta_{z \leq P_{33}(z), z > P_{33}(z)}$ for this difference. Figure A.1 of their paper shows mean values of z_N in the "treated" and "control" groups of 0.795 and 0.863, respectively.[1] The value of bonus fluctuated during their sample period. I use $B = 50\%$ as the modal value, implying $\Delta_{2001,2011}\Delta_{z \leq P_{33}(z), z > P_{33}(z)} = 0.034$. Since these zs apply only to equipment, I report the equipment capital result in their table 2.

Chodorow-Reich et al. (2025) I report their results for domestic-only firms since these firms fit into the theory in Section 2.1.

Kennedy et al. (2022) They estimate: $I_{i,t}/K_{i,t-1} = b_1 d\log(1-\tau) \times \mathbb{I}\text{year} >= 2018 + \text{firm FE} + \text{industry} \times \text{size} \times yearFE$ in a panel of C and S corporations from 2013-2019. They treat $d\log(1-\tau)$ as an endogenous variable and use an indicator for being a C-corporation as the excluded instrument, since the corporate rate cut applied to C but not S corporations. Since the expensing provisions applied to both, $d\log(1-\Gamma)$ is the same for both C and S corporations and its effect should be absorbed by the industry-size-year fixed effects.

Caballero, Engel and Haltiwanger (1995) Their Appendix B motivates their regression specification by starting from the Cobb-Douglas case with (ignoring productivity) $Y_{i,t} = K_{i,t}^{\gamma}$ (see equation (15)) and the associated first order condition for steady state capital $\gamma K_i^{\gamma-1} = R_{i,t}$, where $R_{i,t}$ here denotes the steady state user cost, which may vary over time. Take logs of the production function to find: $y_{i,t} - k_{i,t} = (\gamma - 1)k_{i,t}$. Subtract $k_{i,t}$ from both sides of the first order condition (in logs) to find:

$$k_i - k_{i,t} = -\frac{1}{1-\gamma} r_{i,t} - k_{i,t} = \frac{1}{1-\gamma}\left(y_{i,t} - k_{i,t} - r_{i,t}\right).$$

[1] The precise values were provided via personal communication from the authors.

Caballero, Engel and Haltiwanger (1995) insert an *ad hoc* scalar multiplying $r_{i,t}$ and assume the left hand side is stationary to motivate a cointegrating relationship between the log capital-output ratio and the log user cost.

An alternative motivation without requiring the *ad hoc* scalar starts from CES. Using equation (22), take logs and rearrange to find:

$$k_{i,t} = \left(\eta + \frac{1-\eta}{(\alpha+\beta)}\right) y_{i,t} - \eta r_{i,t}.$$

Thus, a long-run cointegrating relationship between the log capital-output ratio and log user cost holds exactly only under constant returns to scale, $\alpha + \beta = 1$.

Chirinko, Fazzari and Meyer (1999) Let $K^*_{i,t}$ denote the firm's "desired capital" at date t, defined as the solution to equation (22) taking $Y_{i,t}$ as given. Instead of an explicit function for adjustment costs, Chirinko, Fazzari and Meyer (1999) assume that net investment is a function of lagged changes in log desired capital:

$$\frac{I_{i,t}}{K_{i,t-1}} = \delta + \sum_{h=0}^{H} \omega_h \Delta k^*_{i,t-h},$$

where $\sum_{h=0}^{H} \omega_h = 1$. Substitute for $\Delta k^*_{i,t-h}$ using equation (22):

$$\frac{I_{i,t}}{K_{i,t-1}} = \delta + \sum_{h=0}^{H} \omega_h \left(-\eta \Delta r_{i,t-h} + \left(\eta + \frac{1-\eta}{\alpha+\beta}\right) \Delta y_{i,t-h}\right) + \epsilon_{i,t},$$

where $\epsilon_{i,t}$ is a summation of past productivity changes.

Dwenger (2014) Dwenger assumes that current log capital is a function of lagged capital and current and lagged desired capital. After substituting using equation (22) as above:

$$k_{i,t} = \phi k_{i,t-1} + \sum_{h=0}^{H} \omega_h \left(-\eta r_{i,t-h} + \left(\eta + \frac{1-\eta}{\alpha+\beta}\right) y_{i,t-h}\right) + \epsilon_{i,t}.$$

Dwenger (2014) manipulates this expression as follows. In a steady state, we must have:

$$(1-\phi)\, k_i = k_i \sum_{h=0}^{H} \omega_h.$$

Using this fact, one can show that for any x:

$$\sum_{h=0}^{H} \omega_h x_{i,t-h} = (1-\phi)\, x_{i,t-1} - \sum_{h=0}^{H-1} \mu_h \Delta x_{i,t-h},$$

$$\text{where: } \mu_0 = -\omega_0,$$

$$\mu_h = \sum_{j=h+1}^{H} \omega_j \ \forall k > 0.$$

Thus:

$$k_{i,t} = \phi k_{i,t-1} - (1-\phi)\,\eta r_{i,t-1} + \frac{(1-\phi)\,(1-\eta)}{\alpha+\beta} y_{i,t-1} + \sum_{h=0}^{H-1} \mu_h \left(-\eta r_{i,t-h} + \left(\eta + \frac{1-\eta}{\alpha+\beta} \right) \Delta y_{i,t-h} \right) + \epsilon_{i,t}.$$

Dwenger (2014) also includes a sample attrition term in her preferred specification.