The Macroeconomic Effects of Business Tax Cuts

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Abstract

This paper studies the macroeconomic effects of business tax cuts using a dynamic general equilibrium model that incorporates endogenous debt and equity financing, interest deductibility, and accelerated capital depreciation. A cut in the tax rate stimulates business investment and output persistently, but the size of the effects is small. On impact, a ten percentage point permanent tax cut raises investment and output by 2 percent and 0.4 percent, respectively. The cumulative tax multiplier ranges from -0.4 in the initial year to -0.6 after ten years. The model would predict more expansionary effects without debt financing and accelerated depreciation. The multiplier of investment tax credits is larger in absolute value than the tax rate multiplier. The multiplier of depreciation allowances is much smaller on impact than at long horizons.

Keywords: Interest deductibility, tax shields, tax multiplier, dynamic general equilibrium.

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1 Introduction

A cost-of-capital argument suggests that business tax cuts stimulate investment, but their effect is small when investment is financed through debt and tax depreciation is fast. A business income tax raises the cost of capital and discourages investment, so a tax cut stimulates it. The tax cut, however, works through a second channel. Businesses can deduct their interest expenses and capital depreciation from their taxable income, and these two tax shields lower the cost of capital and raise investment. By reducing the two tax shields, the tax cut lowers investment. This second channel is stronger when investment is financed through debt rather than equity, and tax depreciation is faster than economic depreciation (Fullerton 1999; Barro and Furman 2018).

There is evidence that debt financing and accelerated depreciation are empirically relevant for investment decisions, suggesting that they are important for the effect of business tax cuts on investment. Several studies show that faster depreciation stimulates investment.[1] Other studies provide indirect evidence that debt financing affects investment by showing that the weighted average cost of capital, which depends on debt financing, affects investment decisions.[2]

[1]These studies identify the effect of faster depreciation by exploiting that only shorter-duration assets were eligible for the increases in bonus depreciation in 2001-2004 and 2008-2010. Using quarterly data for 36 types of capital, House and Shapiro (2008) document that eligible investment increased sharply in response to the increase in bonus depreciation in 2001-2004, estimating an elasticity of investment to the bonus depreciation rate between 6 and 14. Using firm-level data, Zwick and Mahon (2017) also find a strong response of eligible investment to bonus depreciation, estimating that the increases in bonus depreciation in 2001-2004 and in 2008-1010 raised investment in eligible capital relative to ineligible capital by 10.4 percent and 16.9 percent, respectively. See also Ohrn (2018, 2019) and Curtis et al. (2022).

[2]Bierman (1993) summarizes the evidence from a survey of capital budgeting at the Fortune 100 industrial firms (74 firms of the 100 firms responded) and reports that 93 percent of the firms that responded (68 of the 74 firms) use the weighted average cost of capital to evaluate the discounted value of new investments. Using firm-level data, Frank and Shen (2016) estimate a significant effect

In this paper, I study the macroeconomic effects of business tax cuts using a dynamic general equilibrium model that incorporates endogenous debt and equity financing, interest deductibility, and accelerated depreciation of capital. Although a few previous studies (House and Shapiro 2006; Occhino 2019, 2022; Zeida 2022; Furno 2022) have introduced investment expensing or accelerated depreciation in general equilibrium models, this is the first paper that adds interest deductibility with a mix of debt and equity financing.

Capital depreciation is modeled as in Occhino (2022), allowing for the immediate deduction of a fraction of investment expenses (partial investment expensing or bonus depreciation) and the depreciation of the remaining capital at a faster rate than economic depreciation (double declining balance method).

The financing choice of firms is modeled after the trade-off theory of capital structure (Kraus and Litzenberger 1973; Brennan and Schwartz 1978; Leland 1994). On the one hand, debt provides a tax benefit since firms can deduct the debt interest expenses but not the return on equity. On the other hand, debt generates agency and transaction costs associated with financial distress and the probability of default. Firms choose the share of financial capital that is debt, weighing benefits and costs. Intuitively, as the tax rate increases, the tax benefit of debt increases, and firms substitute debt for equity.[3]

According to the model, a ten percentage point permanent cut in the business

of the weighted average cost of capital on corporate investment, although the sign of the effect depends on how the cost of equity is measured. In their paper, the average cost of debt is about half the cost of equity, and debt provides a tax benefit, so debt financing reduces the weighted average cost of capital.

[3]de Mooij (2011) applies meta-regression techniques to the results of a large set of empirical studies and finds that a one percentage point increase in the corporate tax rate raises the debt-asset ratio by between 0.17 and 0.28 percentage points. Ohrn (2018) also estimates a significant positive effect of the tax rate on leverage using quasi-experimental variation in the tax rate created by the Domestic Production Activities Deduction across industries and firm sizes. MacKie-Mason (1990) and Graham (1996) also study the effect of corporate taxation on capital structure.

income tax rate raises business investment by 2 percent in the initial year, with the effect persisting over time. The effect on output is small in the initial year, only 0.4 percent, although it increases to 0.7 percent after ten years. The cumulative tax multiplier is correspondingly small, ranging from -0.4 in the initial year to -0.6 after ten years.

The expansionary effects of tax cuts are small because firms partially finance their investment through debt, and tax depreciation is faster than economic depreciation. The model's effects depend on business financing and capital depreciation in the same way as in the cost-of-capital argument outlined at the beginning of this introduction. The faster the capital depreciation allowed by the tax system, the smaller the expansionary effects of tax cuts (Occhino 2019; Furno 2022). The higher the share of financial capital that is debt, the smaller the expansionary effects of tax cuts. Without debt financing and accelerated depreciation, the effect on output would be approximately double in the initial year and three times as large after ten years.

Stated alternatively, if the model did not incorporate debt financing and accelerated depreciation, it would significantly over-predict the expansionary effects of tax cuts. This result suggests that, more generally, including debt financing and accelerated depreciation is quantitatively important when using models to predict business tax effects and multipliers.

The effects of business tax cuts would be even less expansionary if not for their distributional effects. Business tax cuts redistribute resources from households to businesses and raise household labor supply and business output. This distributional channel accounts for most of the increase in output on impact and more than half after ten years.

The tax multiplier varies significantly depending on the tax policy tool. The tax multiplier measures the change in output for a given change in the business tax liability. In turn, the change in the business tax liability can be generated by a change in various tax policy tools, for instance, the tax rate, depreciation allowances, or investment tax credits. The cumulative multiplier of the investment tax credit, which ranges from -0.7 in the initial year to -1.1 after ten years, is more than 50 percent larger than the tax rate multiplier. In other words, an increase in the investment tax credit causes an output expansion that is more than 50 percent larger than the one caused by a tax rate cut, provided that the two policy changes generate the same decrease in the business tax liability. Also, the cumulative tax multiplier of the depreciation allowance, which ranges from -0.1 in the initial year to -0.5 after ten years, is much smaller in the short run than in the long run since an increase in the depreciation allowance tends to generate larger decreases in the business tax liability early and smaller decreases later.

Related literature

The model in this paper builds upon the one in Occhino (2022), who studies the macroeconomic effects of the 2017 tax reform. Some model features are the same, including accelerated depreciation and the distinction between households and business owners, which captures the distributional effects of business tax changes. The main difference is that, here, firms finance investment with an endogenous mix of debt and equity, while there, they use only debt. Some other differences are due to the different focus of the two papers. Occhino (2022) adds several model features necessary to study the effects of the 2017 tax reform (C corporations and pass-through businesses; equipment, structures, and R&D; financial frictions and credit spread; constant inflation; and capital-adjustment costs). Another difference is that this paper includes a consumption tax.

This paper belongs to the vast literature that uses dynamic general equilibrium models to study the macroeconomic effects of tax changes. Models have various features: heterogeneous households and incomplete markets in Domeij and Heathcote (2004); price stickiness and rule-of-thumb consumers in Forni, Monteforte, and Sessa (2009); financial frictions in Fernández-Villaverde (2010); heterogeneous households, life cycle, occupational choice, and entrepreneurial human capital in Zeida (2022). House and Shapiro (2006) show that while immediate tax cuts stimulate investment and output, delayed tax cuts reduce them. Zubairy (2014) estimates that the effects of tax cuts build over time since they are primarily driven by the response of investment. Sims and Wolff (2018) show that tax cuts are more stimulative during expansions. Castelletti Font, Clerc, and Lemoine (2018) find that capital income tax cuts are more expansionary than labor income tax cuts. Slavík and Yazici (2019) highlight the benefits of eliminating the capital tax differential between equipment and structures. Furno (2022) shows that the stimulative effects of corporate tax cuts were smaller in 2017 than in the 1960s because in 2017, tax depreciation was faster, and the corporate share of economic activity lower. Bhattarai, Lee, Park, and Yang (2022) show that permanent cuts in the capital tax rate are more expansionary when they are financed by cuts in lump-sum transfers than by hikes in distortionary taxes. Relative to this literature, I introduce interest deductibility with endogenous debt and equity financing and include the distributional effects of business tax changes.

This paper also adds perspective to the empirical literature that estimates the tax multiplier and the macroeconomic effects of tax changes using structural or narrative identification methods (Blanchard and Perotti 2002; Mountford and Uhlig 2009; Romer and Romer 2010; Barro and Redlick 2011; Favero and Giavazzi 2012; Mertens and Ravn 2013, 2014; Caldara and Kamps 2017; Geerolf and Grjebine 2019; Nguyen, Onnis, and Rossi 2021). This literature estimates the effects of changes in the tax liability, not necessarily changes in the tax rate. For instance, to focus on a study of business taxes, Mertens and Ravn (2013) estimate the effects of changes in corporate income tax liability. However, the tax liability changes they consider in their study are mostly driven by increases in depreciation allowances and investment tax credits—Changes in the corporate income tax rate play some role in only 3 of the 16 tax liability changes. Hence, their estimates mainly refer to the effects of depreciation allowances and investment tax credits, not the corporate income tax rate. This paper highlights that the macroeconomic effects of changes in the corporate tax rate can be very different (even the opposite when investment is financed only through debt) from the effects of changes in depreciation allowances and investment tax credits, so they can be very different from the effects of the tax liability changes estimated by the empirical literature.

Finally, this paper builds upon the vast literature that examines the effect of the tax system and business financing on investment based on partial-equilibrium, user-cost-of-capital frameworks. Many articles show how parameters that describe the tax system, the firm, or the economy, (for instance, the tax rate, tax credits, capital depreciation allowances, debt financing, the inflation rate, and the interest rate) affect the user cost of capital, the marginal effective tax rate, and business investment in partial equilibrium (Hall and Jorgenson 1967; King and Fullerton 1984; Gravell 1994; Fullerton 1999; Auerbach 2002; Creedy and Gemmell 2017). Other articles empirically estimate the effect of the tax system and business financing on the user cost of capital, the marginal effective tax rate, and business investment. Barro and Furman (2018) derive the long-run effects of the 2017 tax reform using a partial-equilibrium, cost-of-capital neoclassical framework. CBO (2014) estimates widely different marginal effective tax rates across investments (ranging from −42 percent to 47 percent) depending on the type of asset (structures, equipment, or software) and the source of financing (equity or debt): The marginal effective tax rate is much lower for debt-financed investment and for assets for which tax depreciation is faster than economic depreciation. Fernández-Rodríguez, García-Fernández, and Martínez-Arias (2021) study the business and country determinants of the effective tax rate in emerging economies. Vartia (2008) constructs a measure of the user cost of capital and estimates a negative effect of the user cost of capital on the investment-capital ratio using industry-level OECD data. Since the measure of the user cost of capital decreases as the present value of depreciation allowances increases, Vartia (2008) provides indirect empirical evidence that depreciation allowances raise the investment-capital ratio. Ohrn (2018) uses quasi-experimental variation in the tax rate created by the Domestic Production Activities Deduction across industries and firm sizes and estimates that higher corporate income tax rates and faster depreciation stimulate investment. Álvarez-Ayuso, Kao, and Romero-Jordán (2018) estimate that tax credits boost long-run R&D investment. Similarly, von Brasch et al. (2021) estimate that investment tax credits raise long-run output by lowering the user cost of R&D capital and stimulating R&D investment and productivity. In this paper, I incorporate the key elements of this literature into a dynamic general equilibrium model. I study the effects of permanent and temporary tax policy changes, examine the short and the long run, and include the general-equilibrium effects through the interest rate, wage rate, and labor supply.

In the rest of the paper, Section 2 details the model and explains why the effects of tax cuts depend on debt financing and capital depreciation; Section 3 describes the calibration, results, and sensitivity analysis; and Section 4 concludes.

2 Model

In the model, there is a continuum of representative households of measure one, a continuum of representative firms of measure one, and a government. Firms are owned by agents that are distinct from households. Households supply labor and financial capital to firms. Firms invest, produce, and pay taxes on their income after deducting tax depreciation and interest expenses. The government uses lump-sum transfers to households to balance its intertemporal budget constraint.

2.1 Firms

2.1.1 Capital, depreciation, and production

The firm begins period t with economic capital, k_t (capital, for short), hires labor, l_t, at the wage rate, w_t, produces, and sells output,

$$y_t \equiv Af(k_t, l_t), \tag{1}$$

where $A > 0$, $f(k, l) \equiv k^{\alpha} l^{1-\alpha}$, and $\alpha \in (0, 1)$. The firm invests x_t, so capital evolves according to the law of motion:

$$k_{t+1} = (1 - \delta)k_t + x_t, \tag{2}$$

where $\delta \in (0, 1)$ is the economic depreciation rate.

2.1.2 Tax capital and tax depreciation

Tax depreciation is faster than economic depreciation. Capital is depreciated at the tax depreciation rate $\tilde{\delta} \in [\delta, 1)$, capturing the tax provision that allows the use of an accelerated method to depreciate assets—the double declining balance method. Furthermore, a fraction κ_t of investment expenses can be deducted (*expensed*) from taxable income in the same period in which the investment expenses are incurred. The investment expensing fraction, κ_t, captures two forms of depreciation allowances: the bonus depreciation of equipment that allows deducting immediately part of the investment expenses in equipment; and the provision, which expired in 2022, that allowed deducting immediately the investment expenses in R&D. I assume that κ_t follows the first-order autoregressive process:

$$\kappa_{t+1} - \kappa = \rho_{\kappa}(\kappa_t - \kappa) + \epsilon_{\kappa,t+1} \tag{3}$$

where $\kappa \in [0, 1]$, $\rho_{\kappa} \in [0, 1]$, and $\epsilon_{\kappa,t+1}$ is a policy shock distributed as a normal random variable with a mean equal to zero.

Because of the difference between tax depreciation and economic depreciation, we need to keep track of tax capital separately from economic capital. Let $\tilde{k}_t$ be tax capital (the capital level for the tax system) at the beginning of period t. Then, tax depreciation is

$$D_t = \tilde{\delta}\tilde{k}_t + \kappa_t x_t, \tag{4}$$

and tax capital evolves according to the law of motion:[4]

$$\tilde{k}_{t+1} = (1 - \tilde{\delta})\tilde{k}_t + (1 - \kappa_t)x_t. \tag{5}$$

2.1.3 Debt and equity financing

Turning to the financing side, let v and e_t be, respectively, the inside equity and outside equity outstanding at the beginning of period t, and let

$$E_t \equiv v + e_t \tag{6}$$

be total equity, the sum of inside and outside equity. The constant $v > 0$ represents the inside equity owned by the business owners while e_t represents the outside equity issued by the firm and sold to the households to finance investment—Myers (2000) is a seminal article modeling the outside equity financing decision by insiders such as managers and entrepreneurs.

The firm finances its investment with a mix of debt, b_t, and outside equity, e_t. While debt includes all financial assets whose return can be deducted from taxable income, outside equity includes all assets whose return cannot be deducted from taxable income, such as preferred equity. Let r_t and r_t^e be, respectively, the interest rate on debt and the rate of return on equity. Every period, the firm repays $(1 + r_t)b_t + (1 + r_t^e)e_t$ and issues new debt, b_{t+1}, and outside equity, e_{t+1}.

[4] In the case where $\tilde{\delta} = \delta$ and $\kappa_t = \kappa$ for all t, the model becomes simpler and easier to solve. Tax capital becomes proportional to economic capital ($\tilde{k}_t = (1 - \kappa)k_t$ for all t), and $\tilde{k}_t$ can be dropped from the list of state variables.

The firm's financing choice is modeled after the trade-off theory of capital structure. On the one hand, debt provides a tax benefit—The firm can deduct the interest expenses incurred on its debt, $r_t b_t$, but not the return on equity, $r_t^e e_t$. On the other hand, debt generates financial distress costs, i.e., agency and transaction costs associated with financial distress and the probability of default, as in the trade-off theory of capital structure. According to Myers (1984): "Costs of financial distress include the legal and administrative costs of bankruptcy, as well as the subtler agency, moral hazard, monitoring and contracting costs which can erode firm value even if formal default is avoided." Barro and Furman (2018) introduce similar "costs implied by the positive effect of leverage on a corporation's probability of default and bankruptcy".

I model the financial distress costs as an increasing, convex function of the share of financial capital that is debt. Let

$$a_t \equiv b_t + v + e_t \tag{7}$$

be the firm's total financial capital, the sum of debt and total equity, and let

$$\theta_t \equiv \frac{b_t}{a_t} \tag{8}$$

be the share of financial capital that is debt, so

$$b_t \equiv \theta_t a_t, \tag{9}$$

$$e_t \equiv (1 - \theta_t)a_t - v. \tag{10}$$

The financial distress costs are

$$w(\theta_t)a_t, \tag{11}$$

where $w(\theta) \equiv \Psi\theta^{1+1/\psi}$, $\Psi > 0$, and $\psi > 0$. A higher debt share of financial capital, θ_t, raises the tax benefit of debt and the financial distress costs. The firm chooses the mix of debt and equity, θ_t, balancing the benefits and costs of debt financing.

2.1.4 Taxable income and tax liability

Taxable income, I_t, is obtained by subtracting labor costs, tax depreciation, and interest expenses from revenue:

$$I_t = y_t - w_t l_t - D_t - r_t b_t. \tag{12}$$

The last two terms are the tax shields provided by capital depreciation and interest deductibility, respectively.

The firm pays income taxes at the tax rate τ_t but receives an investment tax credit equal to a fraction χ_t of its investment expenses, so the tax liability is

$$X_t = \tau_t I_t - \chi_t x_t. \tag{13}$$

The business income tax rate, τ_t, and the investment tax credit, χ_t, follow the first-order autoregressive processes:

$$\tau_{t+1} - \tau = \rho_\tau(\tau_t - \tau) + \epsilon_{\tau,t+1} \tag{14}$$

$$\chi_{t+1} - \chi = \rho_\chi(\chi_t - \chi) + \epsilon_{\chi,t+1} \tag{15}$$

where $\tau \in (0,1)$, $\chi \in [0,1)$, $\rho_\tau \in [0,1]$, and $\rho_\chi \in [0,1]$. The policy shocks, $\epsilon_{\tau,t+1}$ and $\epsilon_{\chi,t+1}$, are distributed as normal random variables with means equal to zero.

2.1.5 Optimization problem

The dividend distributed by the firm is obtained by summing revenue and cash flow from financing and subtracting labor costs, investment, tax liability, and financial distress costs:

$$d_t = y_t - w_t l_t - x_t - X_t + [b_{t+1} + e_{t+1} - (1 + r_t)b_t - (1 + r_t^e)e_t] - w(\theta_t)a_t. \tag{16}$$

Substituting the expressions for D_t, I_t, and X_t from (4), (12), and (13) into (16), we obtain

$$d_t = y_t - w_t l_t - x_t - \tau_t(y_t - w_t l_t - \tilde{\delta}\tilde{k}_t - \kappa_t x_t - r_t b_t) + \chi_t x_t + b_{t+1} +$$
$$e_{t+1} - (1 + r_t)b_t - (1 + r_t^e)e_t - w(\theta_t)a_t$$
$$d_t = (1 - \tau_t)(y_t - w_t l_t) - (1 - \tau_t\kappa_t - \chi_t)x_t + \tau_t\tilde{\delta}\tilde{k}_t + b_{t+1} +$$
$$e_{t+1} - [1 + r_t(1 - \tau_t)]b_t - (1 + r_t^e)e_t - w(\theta_t)a_t.$$

Then, substituting the expressions for y_t, b_t, and e_t from (1), (9), and (10), we obtain

$$d_t = (1 - \tau_t)[Af(k_t, l_t) - w_t l_t] - (1 - \tau_t\kappa_t - \chi_t)x_t + \tau_t\tilde{\delta}\tilde{k}_t + \theta_{t+1}a_{t+1} +$$
$$(1 - \theta_{t+1})a_{t+1} - v - [1 + r_t(1 - \tau_t)]\theta_t a_t - (1 + r_t^e)[(1 - \theta_t)a_t - v] - w(\theta_t)a_t$$
$$d_t = (1 - \tau_t)[Af(k_t, l_t) - w_t l_t] - (1 - \tau_t\kappa_t - \chi_t)x_t + \tau_t\tilde{\delta}\tilde{k}_t + a_{t+1} -$$
$$[1 + \theta_t r_t(1 - \tau_t) + (1 - \theta_t)r_t^e + w(\theta_t)]a_t + r_t^e v. \tag{17}$$

Business owners receive dividends d_t, pay dividend taxes at the rate τ^d, consume c_t, and pay consumption taxes at the rate τ^c:

$$(1 + \tau^c)c_t = (1 - \tau^d)d_t. \tag{18}$$

Using (17) and (18),

$$\frac{1 + \tau^c}{1 - \tau^d}c_t = (1 - \tau_t)[Af(k_t, l_t) - w_t l_t] - (1 - \tau_t\kappa_t - \chi_t)x_t + \tau_t\tilde{\delta}\tilde{k}_t + a_{t+1} -$$
$$[1 + \theta_t r_t(1 - \tau_t) + (1 - \theta_t)r_t^e + w(\theta_t)]a_t + r_t^e v. \tag{19}$$

The intertemporal optimization problem solved by the business owners is

$$\max_{\left\{c_t, l_t, x_t, k_{t+1}, \tilde{k}_{t+1}, a_{t+1}, \theta_{t+1}\right\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t u\left(c_t\right) \tag{20}$$

subject to (2), (5), and (19),

given initial values for the state variables $k_0, \tilde{k}_0, a_0, \theta_0$. The utility function $u(c)$ is such that $u'(c) \equiv c^{-\gamma}$, $\gamma > 0$ is the relative risk aversion, $\beta \in (0, 1)$ is the discount factor, and E_0 is the expectation operator.

2.1.6 First-order conditions

Let μ_t, ν_t, and λ_t be the Lagrange multipliers associated with the constraints (2), (5), and (19), respectively. The first-order conditions with respect to c_t, l_t, x_t, k_{t+1}, $\tilde{k}_{t+1}$, a_{t+1}, and θ_{t+1} are, respectively,

$$\beta^t u'(c_t) = \lambda_t \frac{1+\tau^c}{1-\tau^d} \tag{21}$$

$$A\frac{\partial f(k_t, l_t)}{\partial l_t} = w_t \tag{22}$$

$$\lambda_t(1-\tau_t\kappa_t-\chi_t) = \mu_t + \nu_t(1-\kappa_t) \tag{23}$$

$$\mu_t = E_t\left\{\lambda_{t+1}(1-\tau_{t+1})A\frac{\partial f(k_{t+1}, l_{t+1})}{\partial k_{t+1}} + \mu_{t+1}(1-\delta)\right\} \tag{24}$$

$$\nu_t = E_t\left\{\lambda_{t+1}\tau_{t+1}\tilde{\delta} + \nu_{t+1}(1-\tilde{\delta})\right\} \tag{25}$$

$$\lambda_t = E_t\left\{\lambda_{t+1}\left[1+\theta_{t+1}r_{t+1}(1-\tau_{t+1}) + (1-\theta_{t+1})r^e_{t+1} + w(\theta_{t+1})\right]\right\} \tag{26}$$

$$0 = E_t\left\{\lambda_{t+1}\left[r_{t+1}(1-\tau_{t+1}) - r^e_{t+1} + w'(\theta_{t+1})\right]\right\}. \tag{27}$$

The first two conditions have standard interpretations. The Lagrange multiplier λ_t measures the marginal increase in the objective function obtained by relaxing the budget constraint by one unit of dividends. One unit of dividends buys $\frac{1-\tau^d}{1+\tau^c}$ units of consumption after taxes. In turn, one unit of consumption raises the objective function by $\beta^t u'(c_t)$. Then,

$$\lambda_t = \frac{1-\tau^d}{1+\tau^c}\beta^t u'(c_t),$$

which is equivalent to (21). Condition (22) equates the marginal product of labor, $A\frac{\partial f(k_t,l_t)}{\partial l_t}$, to the real wage rate, w_t.

The following three conditions involve the Lagrange multipliers μ_t and ν_t, which measure the marginal increases in the objective function obtained by relaxing the laws of motion of economic capital and tax capital, respectively.

Condition (23) states that the marginal cost of investment equals the marginal benefit. The marginal cost is the product of the shadow price of the budget constraint, λ_t, and the price of investment, $1-\tau_t\kappa_t-\chi_t$, which is less than one because of investment expensing and tax credits. The marginal benefit is the sum of two components: First, investment raises next-period economic capital by one unit, so it raises the objective function by μ_t; Second, investment raises next-period tax capital by $1-\kappa_t$ units, so it raises the objective function by $(1-\kappa_t)\nu_t$.

Condition (24) provides an expression for μ_t, which measures the marginal benefit of one additional unit of next-period economic capital, k_{t+1}. The marginal benefit is the sum of two expected future components. First, one additional unit of k_{t+1} raises the objective function by $\lambda_{t+1}(1-\tau_{t+1})A\frac{\partial f(k_{t+1},l_{t+1})}{\partial k_{t+1}}$ by raising future production and dividends. Second, it raises the objective function by $\mu_{t+1}(1-\delta)$ since it raises k_{t+2} by $1-\delta$ units.

Similarly, condition(25) provides an expression for ν_t, which measures the marginal benefit of one additional unit of next-period tax capital, $\tilde{k}_{t+1}$. The marginal benefit is the sum of two expected future components. First, one additional unit of $\tilde{k}_{t+1}$ raises the objective function by $\lambda_{t+1}\tau_{t+1}\tilde{\delta}$ by raising the future tax shield provided by tax depreciation. Second, it raises the objective function by $\nu_{t+1}(1-\tilde{\delta})$ since it raises $\tilde{k}_{t+2}$ by $1-\tilde{\delta}$ units.

The final two conditions capture the trade-offs between the benefits and costs of financing. Condition (26) states that the marginal benefit of raising financial capital equals the marginal cost. On the one hand, receiving one additional unit of financial capital, a_{t+1}, relaxes the current-period budget constraint by one unit. On the other hand, it tightens the next-period budget constraint by $1+\theta_{t+1}r_{t+1}(1-\tau_{t+1})+(1-\theta_{t+1})r^e_{t+1}+w(\theta_{t+1})$ units by raising the return on financial capital (reduced by the tax benefit of debt) and the financial distress costs.

Condition (27) states that the marginal benefit of substituting debt for equity equals the marginal cost. Borrowing one additional unit of debt while simultaneously issuing one less unit of outside equity has three effects: It raises the tax shield provided by interest deductibility by $r_{t+1}\tau_{t+1}$; It raises the financial distress costs by $w'(\theta_{t+1})$; And it changes the return paid on financial capital by the spread $r_{t+1}-r^e_{t+1}$, which can be positive, negative, or zero—It is zero in the equilibrium of this model.

Notice that, in a partial-equilibrium deterministic version of the model (holding r_{t+1} and r^e_{t+1} constant), (27) would imply that the debt share of financial capital, θ_{t+1}, increases with the tax rate, τ_{t+1}. Intuitively, an increase in the tax rate raises the tax shield provided by interest deductibility and the tax benefit of debt and encourages firms to substitute debt for equity financing.

2.2 Households

Households consume $\tilde{c}_t$, pay consumption taxes at the rate τ^c, receive a constant endowment of goods, y^H, supply labor, n_t, receive wages, $w_t n_t$, and pay taxes on labor income at the rate τ^w. They lend B_{t+1} to the government and supply financial capital to firms in the form of debt, b_{t+1}, and equity, e_{t+1}. They receive the gross return from firms and the government, receive lump-sum transfers, Z_t, from the government, and pay taxes on capital income at the tax rate τ^r. Then, the households' budget constraint is

$$\begin{aligned}(1+\tau^c)\tilde{c}_t + b_{t+1} + e_{t+1} + B_{t+1} = y^H + (1-\tau^w)w_t n_t +\\ [1+(1-\tau^r)r_t]b_t + [1+(1-\tau^r)r^e_t]e_t + [1+(1-\tau^r)r^B_t]B_t + Z_t.\end{aligned} \tag{28}$$

The households' optimization problem is

$$\max_{\{\tilde{c}_t, n_t, e_{t+1}, b_{t+1}, B_{t+1}\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \tilde{\beta}^t [u(\tilde{c}_t) - v(n_t)] \tag{29}$$

$$\text{subject to (28),}$$

where the utility function $u(\tilde{c})$ is the same as the one for firm owners, $v(n) \equiv \Phi n^{1+1/\varphi}$, $\Phi > 0$, $\varphi > 0$, and $\tilde{\beta} > 0$.

The first-order conditions are

$$\frac{v'(n_t)}{u'(\tilde{c}_t)} = \frac{1-\tau^w}{1+\tau^c} w_t \tag{30}$$

$$1 = E_t \left\{ \frac{\tilde{\beta} u'(\tilde{c}_{t+1})}{u'(\tilde{c}_t)} \left[1 + (1-\tau^r) r_{t+1}\right] \right\} \tag{31}$$

$$1 = E_t \left\{ \frac{\tilde{\beta} u'(\tilde{c}_{t+1})}{u'(\tilde{c}_t)} \left[1 + (1-\tau^r) r^e_{t+1}\right] \right\} \tag{32}$$

$$1 = E_t \left\{ \frac{\tilde{\beta} u'(\tilde{c}_{t+1})}{u'(\tilde{c}_t)} \left[1 + (1-\tau^r) r^B_{t+1}\right] \right\} \tag{33}$$

which implies that, in a linear approximation of the equilibrium, the rates of return on debt, equity, and government debt are equal:

$$r_{t+1} = r^e_{t+1} = r^B_{t+1}. \tag{34}$$

2.3 Government

The government receives a constant endowment of goods, y^G, issues debt, B_{t+1}, and collects tax revenue, T_t, from households and firms:

$$T_t \equiv X_t + \tau^w w_t n_t + \tau^r (r_t b_t + r^e_t e_t + r^B_t B_t) + \tau^d d_t + \tau^c (c_t + \tilde{c}_t). \tag{35}$$

It uses the proceeds to finance government spending, G, distribute lump-sum transfers to households, Z_t, and repay the gross-of-interest debt to households:

$$G + Z_t + (1 + r^B_t) B_t = y^G + T_t + B_{t+1}. \tag{36}$$

I assume that the lump-sum transfers, Z_t, adjust so that government debt is stationary and an equilibrium exists. Provided that an equilibrium exists, the timing of the adjustment in Z_t affects only the evolution of government debt and (because tax revenue depends on government debt) tax revenue. It does not matter for the dynamics of the other variables since households hold all the government debt, and Ricardian equivalence applies.

More specifically, I assume that Z_t depends on changes in government debt 20 years earlier:

$$Z_t = Z - r(B_{-20} - B). \tag{37}$$

With this assumption, in the first 20 years after any tax policy change (the time frame that I use in all the figures), Z_t remains constant, so any changes in government debt and tax revenue are due only to the tax policy change, not to changes in Z_t.

2.4 Equilibrium conditions and tax multiplier definitions

Let

$$C_t \equiv c_t + \tilde{c}_t \tag{38}$$

be aggregate private consumption, the sum of consumption of business owners and households, and let

$$Y_t \equiv y_t + y^H + y^G \tag{39}$$

be GDP, the sum of the output of businesses, households, and the government.

The equilibrium condition of the goods market equates the sum of private and public consumption, investment, and financial distress costs to GDP, while the equilibrium condition of the labor market equates labor demand and labor supply:

$$C_t + G + x_t + w(\theta_t)a_t = Y_t \tag{40}$$

$$l_t = n_t. \tag{41}$$

Finally, I define two tax multipliers, one in terms of the business tax liability, X_t, and the other in terms of the government tax revenue, T_t. The cumulative tax multiplier, M_t^X, of a tax policy shock that occurs at time 0 is the ratio of the discounted cumulative response of business output to the discounted cumulative response of business tax liability:

$$M_t^X \equiv \frac{\sum_{s=0}^{t} \left[(y_s - y)/R_s\right]}{\sum_{s=0}^{t} \left[(X_s - X)/R_s\right]} \tag{42}$$

where y and X are the steady-state values, $R_0 \equiv 1$, and $R_s \equiv \prod_{j=1}^{s}(1+r_j)$ for $s \geq 1$ (Ramey 2019).

The alternative cumulative tax multiplier, M_t^T, is the ratio of the discounted cumulative response of business output to the discounted cumulative response of government tax revenue:

$$M_t^T \equiv \frac{\sum_{s=0}^{t}\left[(y_s - y)/R_s\right]}{\sum_{s=0}^{t}\left[(T_s - T)/R_s\right]} \tag{43}$$

where T is the steady-state value.

I will focus on M_t^X for comparability with the empirical literature on the business tax multiplier, which estimates the effects of changes in the business tax liability (Mertens and Ravn 2013). However, I will also show M_t^T in the figures and discuss some differences between M_t^X and M_t^T.

2.5 Why the effect of tax cuts depends on debt financing and accelerated depreciation

The model captures why debt financing and accelerated depreciation are so important for the effect of tax changes on investment. The reason is the tax treatment of investment and interest expenses.

A business tax cut has two partial-equilibrium effects on business investment, working in opposite directions.

First, to the extent that businesses cannot immediately deduct their investment expenses, a business income tax acts as a tax on investment. Hence, a tax cut lowers the user cost of capital and stimulates investment. This effect is strong when tax depreciation is as fast as economic depreciation ($\kappa = 0$ and $\tilde{\delta} = \delta$) and weakens when businesses can deduct investment expenses earlier through bonus depreciation and other forms of accelerated depreciation ($\kappa > 0$ and $\tilde{\delta} > \delta$). In the limit, if all investment expenses can be immediately deducted (full expensing of investment, $\kappa = 1$), this effect disappears, as shown in standard investment models.

Second, to the extent that businesses finance their investment through debt, the deductibility of interest expenses provides a tax shield that increases with the tax rate. Hence, a tax rate cut lowers the tax shield, raises the user cost of capital, and discourages investment. This effect is strong when investment is financed through debt ($\theta = 1$) and weakens when the debt share decreases. In the limit, if all investment is financed through equity ($\theta = 0$), this effect disappears.

The balance of these two partial-equilibrium effects depends on how fast businesses can depreciate their capital for tax purposes and whether they finance their investment through equity or debt. A tax cut stimulates investment if tax depreciation is slow and the debt share is low, while it discourages investment if tax depreciation is fast and the debt share is high. Fullerton (1999) shows how interest deductibility and depreciation allowances can lead to negative effective marginal tax rates on investment: "Thus we get a zero marginal effective tax rate either with expensing *or* with debt finance. As a consequence, we get a negative effective tax rate with expensing *and* debt finance."

Appendix A illustrates how the effect of a tax cut on investment depends on debt financing and accelerated depreciation studying the steady state of a simplified, partial-equilibrium version of the model. It shows that a tax cut stimulates investment when investment is financed through equity ($\theta = 0$) or when investment expenses cannot be immediately deducted ($\kappa = 0$). The stimulative effect of a tax cut on investment decreases and turns contractionary as θ and κ increase. A tax cut discourages investment when investment is financed through debt ($\theta = 1$) or when investment expenses can be immediately deducted ($\kappa = 1$).

3 Results

3.1 Parameters and steady-state values

Parameters and steady-state values are listed in Table 1.

A few standard parameters are set in line with the literature. One period corresponds to one year. The steady-state real interest rate is $r = 0.04$. Given r and the tax rates, the preferences discount factors of households and business owners are set to satisfy the first-order conditions in steady state ($\beta = 0.963$, $\tilde{\beta} = 0.967$). The relative risk aversion is $\gamma = 2$. The Frisch elasticity of labor supply is $\varphi = 0.5$, and the utility-function parameter Φ is set so that $l = 1/3$ in steady state. The exponent of the production function is $\alpha = 0.33$, and the economic depreciation rate is $\delta = 0.1$.

The steady-state level of GDP is normalized to $Y = 1$. The remaining production parameters are set equal to $y^H = 0.125$, $y^G = 0.125$, and $A = 1.30$, which implies $y = 0.75$, to match the fact that in 2013 the household, government, and business sectors accounted, respectively, for 12.5 percent, 12.5 percent, and 75 percent of gross value added (IRS, SOI Tax Stats - Integrated Business Data, Table 1, and BEA, National Income and Product Accounts, Table 1.3.5).

The setting of the tax policy parameters targets their values before the 2017 tax reform. The steady-state business income tax rate equals the corporate tax rate, $\tau = 0.35$.

The investment expensing fraction, κ, is set considering the different types of investment separately. Before the 2017 tax reform, all investment expenses in R&D could be immediately deducted, 50 percent of investment expenses in equipment and software could be immediately deducted (bonus depreciation), and no investment expenses in structures could be immediately deducted. According to the BEA's NIPA accounts, investment in R&D, equipment, software, and structures represent, respectively, 17 percent, 42 percent, 20 percent, and 21 percent of private fixed nonresidential investment. Then, I set the fraction of investment expenses that can be immediately deducted to $\kappa = 1 \times 0.17 + 0.5 \times (0.42 + 0.2) + 0 \times 0.21 = 0.48$.

The tax depreciation rate is double the economic depreciation rate, $\tilde{\delta} = 0.2$, to capture the fact that most businesses use accelerated depreciation (double declining balance method changing to the straight line method at the point at which depreciation deductions are maximized).

The investment tax credit fraction captures the R&D tax credit (Research and Experimentation Tax Credit), which is approximately 6 percent of R&D investment expenses (Office of Tax Analysis 2016 and Barro and Furman 2018). Since investment in R&D is 17 percent of private fixed nonresidential investment, I set $\chi = 0.17 \times 0.06 = 0.01$.

The baseline results refer to the effects of permanent tax policy changes, so I set the first-order autocorrelation coefficients of the policy processes equal to one: $\rho_\tau = 1$, $\rho_\kappa = 1$, and $\rho_\chi = 1$. However, I also show how the results change when the first-order autocorrelation coefficients are less than one, so the tax policy changes are temporary.

The labor income tax rate is $\tau^w = 0.29$ to match the effective marginal federal tax rate on labor income estimated by CBO (2018). The capital income tax rate is $\tau^r = 0.15$ to match the capital gain tax rate on assets held for more than a year for the median taxpayer. The dividend tax rate is $\tau^d = 0.15$ to match the tax rate on qualified dividends for the median taxpayer. The consumption tax rate is $\tau^c = 0.06$ to match the median state sales tax rate.

The steady-state total financial capital is equal to the present discounted value of the firm, $a = 1.3$. To determine the steady-state equity and debt, I turn to the available data on corporations. Corporate debt was approximately 27 percent of corporate equity in 2014-2017 (Debt as a Percentage of the Market Value of Corporate Equities, Nonfinancial Corporate Business, Federal Reserve, FRED), so I set the share of financial capital that is debt equal to $\theta = 0.27/(1 + 0.27) = 0.21$. The values of a and θ imply $E = 1.03$ and $b = 0.273$.

There is large uncertainty about the value of inside equity, v. I set the baseline value of inside equity equal to 50 percent of total equity, $v = 0.5 \times E$, and I show in Section 3.3 that the value of v has negligible effects on the results.

To set the financial distress costs exponent parameter, ψ, notice that $r = r^e$ and the firm's first-order conditions imply

$$
\begin{aligned}
r\tau = w'(\theta) &= \Psi(1+1/\psi)\theta^{1/\psi} \\
\log(r) + \log(\tau) &= \log\left(\Psi(1+1/\psi)\right) + (1/\psi)\log(\theta) \\
\log(\theta) &= \psi\log(r) + \psi\log(\tau) - \psi\log\left(\Psi(1+1/\psi)\right),
\end{aligned}
$$

so ψ is the elasticity of the debt share θ to the business tax rate τ. Then, to calibrate ψ, I look at the response of θ to the 2017 tax reform, which cut the corporate tax rate by 40 percent (a 14 percentage point cut from 0.35 to 0.21). The debt share was about 0.21 in 2017, hardly changed in the following three years, but then declined by 19 percent (a 4 percentage point decline from 0.21 to 0.17). This evidence suggests setting $\psi = 0.19/0.4 = 0.475$.[5] I will also look at the case where the debt share is constant and does not respond to changes in the tax rate ($\psi \to 0$) and the case of unit elasticity ($\psi = 1$). The financial distress costs scale parameter, Ψ, is set to satisfy the firm's first-order conditions. As a result, the steady-state financial distress costs are $w(\theta)a = 0.0012$.

Government spending, G, is 18 percent of GDP. The government lump-sum transfers, Z, are set so that government debt, B, is equal to 76 percent of GDP to match gross federal debt held by the public as a percentage of GDP in 2017. As a result of the calibration, investment is 17.4 percent of GDP, and aggregate consumption is 64.5 percent of GDP.

[5]The value for ψ is very close to the upper bound of the range estimated by de Mooij (2011). He finds that a one percentage point increase in the corporate tax rate raises the debt-asset ratio by between 0.17 and 0.28 percentage points. His finding implies that a 14 percentage point cut in the corporate tax rate, like the one of the 2017 tax reform, lowers the debt-asset ratio by between 2.38 and 3.92 percentage points. Using the steady-state values $\theta = 0.21$ and $\tau = 0.35$, his finding implies an elasticity, ψ, in the range between $0.17 \times \tau/\theta = 0.28$ and $0.28 \times \tau/\theta = 0.47$. The range's upper bound is very close to my baseline value, $\psi = 0.475$.

3.2 Macroeconomic effects of tax policy changes

3.2.1 Tax rate cut

Figure 1 plots the macroeconomic effects of a permanent cut of unitary size in the business income tax rate, τ_t ($\rho_\tau = 1, \epsilon_{\tau,t} = -1$).[6] The responses of x_t, k_t, $\tilde{k}_t$, l_t, y_t, C_t, w_t, a_t, and b_t are divided by their respective steady-state values so that they can be interpreted as percent responses to a one percentage point tax cut. The responses of the other variables are not transformed. In particular, the responses of tax liability, X_t, and tax revenue, T_t, are not transformed so that they can be easily compared.

In the baseline model, shown by the solid line, a one percentage point cut in the tax rate raises business investment by 0.2 percent in the initial year, with the effect persisting over time. The effect on output is small in the initial year, only 0.04 percent, although it increases over time and reaches 0.07 percent after ten years.

The tax cut works through several partial-equilibrium and general-equilibrium mechanisms. First, the tax cut stimulates business investment by lowering the user cost of capital. This effect is attenuated by debt financing and accelerated depreciation, as shown later in this section.

The funding needs created by the increase in investment demand are only partially met by the decrease in the business tax liability, so firms increase their demand for financial capital. The real interest rate rises and encourages households to delay their consumption and leisure, raise their labor supply, and increase their supply of financial capital to firms. Because of the high real interest rate, the response of consumption increases over time, while the response of labor decreases over time.

The tax cut stimulates the labor supply through a distributional channel as well. Since the government adjusts its future lump-sum transfers to households to balance its intertemporal budget constraint, the tax cut is implicitly financed by future cuts in the transfers. Then, the tax cut redistributes resources from households to businesses.

[6] The model is solved using the Dynare software (first-order linear approximation and Klein's QZ decomposition solution method).

The wealth effect lowers households' consumption and leisure and raises their labor supply. As shown at the end of Section 3.3, this distributional channel approximately accounts for all the increase in labor supply and more than half of the increase in output.

The just-described distributional effect is mitigated by dividend and consumption taxes. As the tax cut raises the dividend and consumption of business owners, the tax revenue generated by dividend and consumption taxes increases and lowers the need for future cuts in the government lump-sum transfers to households.

The tax cut stimulates the labor demand as well. The increase in investment raises capital and the marginal product of labor over time, thereby stimulating labor demand.

Labor increases by 0.05 percent in the initial year, driven by increases in labor demand and supply. With higher capital and labor, business output increases and meets the increased investment demand.

The response of the real wage rate balances the opposite effects of labor demand and supply. The real wage rate is negative in the initial year due to the increase in labor supply. However, it becomes positive over time as labor demand increases.

The tax cut reduces the tax advantage of debt. Hence, businesses substitute equity financing for debt financing, decreasing the debt share of financial capital by 0.25 percentage points and debt by 1.2 percent.

The business tax liability and the government tax revenue decrease persistently. The decrease in the government tax revenue is smaller than the decrease in the business tax liability, especially in the longer run, since the revenues from other taxes increase due to the economic expansion. As a result, the tax multiplier defined in terms of government tax revenue, M_t^T, is larger than the one defined in terms of business tax liability, M_t^X, especially in the longer run. While M_t^X ranges from -0.4 in the initial year to -0.6 after ten years, M_t^T ranges from -0.5 in the initial year to -0.9 after ten years.

These predictions can be compared with estimates of tax multipliers from other studies. According to Ramey (2019), "... many estimates of tax multipliers start out low on impact but then build." Focusing on cumulative tax multipliers associated with changes in the corporate income tax or capital tax, New Keynesian DSGE models tend to estimate a range between 0 and -1.5 (largest cumulative multiplier within first 5 years, Table 2 of Ramey 2019). Structural vector autoregressions and narrative identification methods tend to estimate larger tax multipliers, approximately between -1 and -3, but the estimates are generally associated with changes in taxes other than business taxes (Table 2 of Ramey 2019 and Table 1 of van der Wielen 2020).

Figure 1 also shows the role played by debt financing and accelerated depreciation. In the model without debt financing and accelerated depreciation, shown by the dashed line, the tax cut's effect on investment is four times as large. The effect on output is double in the initial year and three times as large after ten years. Section 2.5 explained why the stimulative effect of the tax cut on investment is smaller when investment is debt-financed, and tax depreciation is faster than economic depreciation. Intuitively, with accelerated depreciation and interest deductibility, the business income tax does not distort investment much, so a cut in the business income tax does not stimulate investment much either.

Quantitatively, accelerated depreciation plays a larger role than debt financing because, in the baseline calibration, tax depreciation is fast ($\kappa = 0.48$ and $\tilde{\delta} = 0.2$), while debt financing is limited ($\theta = 0.21$). Comparing the solid and dotted lines, the output response after ten years is about 50 percent larger in the model without debt financing than in the baseline model. Comparing the solid and dashed-dotted lines, the output response after ten years is about 150 percent larger in the model without accelerated depreciation than in the baseline model.

3.2.2 Increases in expensing fraction and tax credit

Figure 2 compares the macroeconomic effects of a cut in the business income tax rate, τ_t, to two alternative tax policy changes: an increase in the investment expensing fraction, κ_t; and an increase in the investment tax credit, χ_t. The size of the first two shocks is 1, while, for better comparability, the size of the tax-credit shock is 0.1 ($\epsilon_{\tau,t} = -1$, $\epsilon_{\kappa,t} = 1$, $\epsilon_{\chi,t} = 0.1$). All policy changes are permanent; that is, the first-order autocorrelations of the policy variables are equal to one ($\rho_\tau = 1$, $\rho_\kappa = 1$, $\rho_\chi = 1$).

Both an increase in the expensing fraction and an increase in the tax credit have qualitatively similar effects on aggregate production to the effect of a cut in the tax rate. All three tax policy changes stimulate investment, labor, and output and affect the real interest rate and wage rate similarly. One difference is that the debt share, θ_t, drops in response to a tax rate cut because the cut reduces the tax advantage of debt, while it hardly responds to the other two policy changes. Another difference regards the dynamics of financial capital, a_t. In response to the tax rate cut and the tax credit increase, firms increase their demand for financial capital to finance their increased investment expenses. However, in response to the expensing fraction increase, another effect prevails. Initially, taxable income, I_t, drops sizeably as tax depreciation increases. Over time, however, taxable income rebounds as tax capital and depreciation decrease. The temporary drop in taxable income decreases the business demand for financial capital, so financial capital decreases.

Regarding the quantitative differences, it is helpful to focus on the cumulative tax multipliers. The first subplot of Figure 3 zooms in on M_t^X, the multiplier defined in terms of business tax liability.

The cumulative tax multiplier of the expensing fraction ranges from -0.1 in the initial year to -0.5 after ten years. It is much smaller in the short run than in the long run since an increase in the expensing fraction tends to generate large decreases in the business tax liability early, when the increase in the expensing fraction raises tax depreciation, and smaller decreases later, when tax capital decreases and lowers tax depreciation.

The cumulative multiplier of the investment tax credit ranges from -0.7 in the initial year to -1.1 after ten years. In the initial year, it is more than 50 percent larger, in absolute value, than the tax rate multiplier. In the longer run, it is about twice as large. It is also much larger than the multiplier of the expensing fraction. A tax credit increase has a large stimulative effect on investment and output because it decreases investment costs one-for-one. In contrast, the effect of the tax rate depends on the levels of debt financing and accelerated depreciation, as we saw in Sections 2.5 and 3.2.1, and the effect of the expensing fraction depends on the tax rate, as can be inferred from the first-order condition (23).

For all three policy changes, the tax multiplier defined in terms of government tax revenue, M_t^T, is larger than the one defined in terms of business tax liability, M_t^X, especially in the longer run (first row of Figure 3). The reason is the one mentioned in the discussion of the tax rate cut: The revenues from other taxes increase due to the economic expansion, so the decrease in the government tax revenue is smaller than the decrease in the business tax liability.

When defining cumulative tax multipliers, the literature uses various discount rates. Using other discount rates conveys the same message. The second row of Figure 3 shows the two tax multipliers computed with a constant discount rate equal to the steady-state value r, setting $R_s \equiv (1+r)^s$ for all $s \geq 0$. The third row shows the two tax multipliers computed with a zero discount rate, setting $R_s \equiv 1$ for all $s \geq 0$. Overall, these measures are very similar to the corresponding ones in the first row.

3.2.3 Persistence of tax policy changes

Figure 4 highlights the large role played by the persistence of tax cuts. The macroeconomic effects of a temporary cut in the tax rate tend to be the opposite of a permanent cut. While a permanent tax cut stimulates investment, a temporary tax cut encourages businesses to delay investment, depressing current investment and raising future investment, as evident in the case of zero autocorrelation (dashed line). The reason is that interest deductibility and accelerated depreciation provide tax shields that increase with the tax rate. When the tax cut is temporary, the tax rate will be higher in the future, so the tax shields will also be higher and will lower the future cost of investing. Since the future benefit of investing is less affected by the persistence of the tax cut, a cost-benefit analysis encourages businesses to delay investing and take advantage of the higher future tax shields.

In response to a temporary tax cut, investment decreases, so firms decrease their demand for financial capital, causing the real interest rate to drop. The drop in the real interest rate decreases the interest expenses and the tax advantage of debt, so the debt share, θ_t, decreases by more than in the case of a permanent cut in the tax rate.

One could also view the difference between the macroeconomic effects of permanent and temporary tax cuts as highlighting the importance of expectations. A tax cut may have expansionary effects if businesses and the public expect it to be permanent but contractionary effects if they expect it to be reversed soon. The role of expectations may help explain why investment did not respond much to the 2017 tax reform. Although the tax reform included some provisions (individual tax cuts stimulating the labor supply, increased bonus depreciation for equipment investment) that likely stimulated business investment, the overall response of business investment was muted. Several factors may have contributed to restraining investment, such as increased tariffs and related economic policy uncertainty in 2018. One factor, however, may have been the expectation that the corporate tax cuts were going to be, at least partially, reversed. This expectation may have encouraged corporations to delay their investment and caused the corporate tax cuts to have contractionary rather than expansionary effects on investment and output (Occhino 2022).

Persistence is less important for the other tax policy changes. Figure 5 shows the macroeconomic effects of the same policy shocks considered in Figure 2, except that the first-order autocorrelations of the policy variables are equal to 0.9, rather than 1 ($\rho_\tau = 0.9$, $\rho_\kappa = 0.9$, $\rho_\chi = 0.9$). Comparing Figures 2 and 5, the macroeconomic effects of temporary increases in the investment expensing fraction and the investment tax credit tend to be similar to the ones of permanent increases. One minor difference is that when the provisions are temporary, businesses have an additional incentive to increase current investment and take advantage of the provisions while they last.

3.3 Sensitivity analysis

The key parameters are the ones that control business financing and capital depreciation. Business financing is controlled by the steady-state debt share, θ, of financial capital and the elasticity, ψ, of the debt share to the tax rate. Capital depreciation is controlled by the steady-state fraction, κ, of investment expenses that can be immediately expensed and the tax depreciation rate, $\tilde{\delta}$.

The steady-state debt share, θ, is important for the effects of tax cuts. Figure 6 shows that, after a permanent tax cut, investment and output increase if investment is financed mainly through equity but decrease if investment is financed mainly through debt. Section 2.5 explains why. Intuitively, if investment is financed through equity, the income tax distorts investment, and a cut in the tax rate stimulates investment. However, if investment is financed partially through debt, another mechanism is at work: Since the tax shield provided by interest deductibility increases with the tax rate, a tax rate cut lowers the tax shield, raises the user cost of capital, and works to discourage investment. When θ is high enough, this mechanism can be so strong that the overall effect of a tax rate cut on investment is negative.

In the case of $\theta = 0.75$, the business tax liability, X_t, increases after the initial period. This response seems counterintuitive since both the tax rate and business output decrease. What drives the increase in X_t is the increase in taxable income,

I_t, which, in turn, is due to a decrease in tax depreciation and interest expenses. The decrease in tax depreciation is caused by the decrease in investment and tax capital. The decrease in interest expenses is caused by the decrease in debt and the real interest rate.

While the results are sensitive to the debt share, θ, they are almost entirely insensitive to the elasticity, ψ, of the debt share to the tax rate, as shown in Figure 7. After a permanent tax cut, the tax advantage of debt decreases, so firms substitute equity for debt and decrease the debt share of financial capital, θ. The higher the elasticity, ψ, the larger the decrease in the debt share. In theory, with a lower debt share, the tax cut stimulates investment more. However, this effect is tiny, so quantitatively, the model results do not depend on ψ.

The steady-state investment expensing fraction, κ, is important for the effects of tax cuts, similarly to the debt share, θ. Figure 8 shows that, after a permanent tax cut, investment increases if the expensing fraction is zero but decreases if businesses can immediately deduct all their investment expenses from their taxable income. Section 2.5 explained why and showed that, in a simplified version of the model, the expensing fraction, κ, and the debt share, θ, affect the investment response to the tax rate similarly. Intuitively, if businesses cannot immediately deduct any investment expenses, the income tax distorts investment, and a cut in the tax rate stimulates investment. However, if businesses can immediately deduct their investment expenses, another mechanism is at work: the immediate full capital depreciation provides a tax shield that increases with the tax rate. Then, a tax rate cut lowers the tax shield and works to discourage investment. When κ is high enough, this mechanism can be so strong that the overall effect of a tax rate cut on investment is negative.

The model results are also sensitive to the tax depreciation rate, $\tilde{\delta}$, as shown in Figure 9. In many ways, the tax depreciation rate, $\tilde{\delta}$, and the investment expensing fraction, κ, have similar effects on the model results. The greater the tax depreciation rate, the faster the depreciation of capital allowed by the tax system and the smaller the tax distortion of investment. Hence, with a greater tax depreciation rate, a tax cut has a smaller effect on tax distortion and investment.

Another parameter that affects the model results is the steady-state investment tax credit, χ. Figure 10 shows that the stimulative effect of a tax cut on investment diminishes when the tax credit gets larger. The reason is that a larger tax credit lowers the importance of the tax rate for the cost of investment. As a result, a tax rate cut is less important for the cost-benefit analysis of investment and stimulates investment less.

The value of inside equity, v, controls only the equity return that firms pay households and affects only the budget constraints of households and firms, not the first-order conditions and equilibrium conditions. For this reason, v has negligible effects on the results, except for the response of financial capital, a_t, as shown in Figure 11.

The sensitivity of the model results to the other, more standard parameters is, overall, in line with what could be expected in calibrated dynamic general equilibrium models. For instance, one parameter value important for the results is the Frisch elasticity of labor supply, φ. As shown in Figure 12, the model response to a tax cut depends on φ intuitively. Larger values of the Frisch elasticity of labor supply lead to larger effects of the tax cut on labor, resulting in larger effects on output and investment.

As we discussed in Section 3.2.1, the tax cut is financed by future cuts in the government transfers to households, so it redistributes resources from households to businesses and creates a wealth effect that raises households' labor supply. To assess the importance of this distributional channel, the dashed line of Figure 13 shows the model response in the case where the tax cut is financed by lump-sum taxes levied on businesses. In each period, newly-introduced business lump-sum taxes are set equal to the decrease in the business income tax liability. This way, the decrease in the business income tax liability is rebated to the government in a lump sum way, eliminating the direct distributional effect of the tax cut. Comparing the dashed line with the solid line, which refers to the baseline model, shows that the assumption about the tax cut financing significantly affects the labor, output, and investment responses. The distributional channel accounts for most of the increase in output on impact and more than half after ten years. It accounts for approximately one-fourth of the increase in investment and all of the increase in labor supply. The tax multipliers are much smaller without the distributional channel.

4 Conclusion

This paper has studied the macroeconomic effects of business income tax cuts using a dynamic general equilibrium model that incorporates endogenous debt and equity financing, interest deductibility, and capital depreciation. According to the model, a ten percentage point permanent cut in the tax rate raises business investment by 2 percent in the initial year, with the effect persisting over time. The effect on output is small: Output rises by 0.4 percent on impact and 0.7 percent after ten years. The cumulative tax multiplier defined in terms of business tax liability ranges from -0.4 in the initial year to -0.6 after ten years. The cumulative tax multiplier defined in terms of government tax revenue is slightly larger (-0.5 in the initial year and -0.9 after ten years) since the business tax cut stimulates economic activity and raises the revenues from other taxes.

Other tax policy tools have different effects. The cumulative multiplier of the investment tax credit (-0.7 in the initial year and -1.1 after ten years) is more than 50 percent larger than the tax rate multiplier since the investment tax credit decreases investment costs one-for-one, while the effect of the tax rate depends on the levels of debt financing and accelerated depreciation. The cumulative multiplier of the depreciation allowance (-0.1 in the initial year and -0.5 after ten years) is much smaller in the short run than in the long run since an increase in the depreciation allowance tends to generate larger decreases in business tax liability early and smaller decreases later.

Debt financing and accelerated depreciation are important for the predicted effects of tax cuts. Without modeling debt financing and accelerated depreciation, the predicted effect on output would be approximately double in the initial year and three times as large after ten years. The persistence of the tax cut also plays a crucial role. While a permanent tax cut stimulates investment, a temporary tax cut encourages businesses to delay investment, depressing current investment and boosting future investment. This mechanism points to the importance of managing expectations while implementing a tax cut: A tax cut may have an immediate contractionary effect if the public expects it to be reversed soon.

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A Analytical results for a partial-equilibrium model

Consider a fixed-labor version of the model ($l_{t+1} = l$). Suppose that the rates of return are exogenous, constant, and equal ($r_{t+1} = r^e_{t+1} = r$). Also, to simplify, the tax depreciation rate is equal to the economic depreciation rate ($\tilde{\delta} = \delta$), the investment expensing fraction is constant ($\kappa_t = \kappa$), and the investment tax credit is equal to zero ($\chi_t = 0$). Finally, to abstract from any effect of tax changes on the capital structure, the debt share is exogenous and constant ($\theta_t = \theta$), and there are no financial distress costs ($\Psi = 0$). We are interested in the steady-state response of business capital k_{t+1} to a permanent change in the tax rate τ_{t+1}.

In this simplified partial-equilibrium model, the optimization problem of the business owner is the same as problem (20), except that l_{t+1} and θ_{t+1} are constant and are not choice variables. The first-order conditions for the other choice variables are the same as the ones of problem (20). In particular, the ones with respect to x_t, k_{t+1}, $\tilde{k}_{t+1}$, and a_{t+1} are, respectively,

$$\begin{aligned}
\lambda_t(1-\tau_t\kappa_t-\chi_t) &= \mu_t+(1-\kappa_t)\nu_t \\
\mu_t &= E_t\left\{\lambda_{t+1}(1-\tau_{t+1})A\frac{\partial f(k_{t+1},l_{t+1})}{\partial k_{t+1}}+\mu_{t+1}(1-\delta)\right\} \\
\nu_t &= E_t\left\{\lambda_{t+1}\tau_{t+1}\tilde{\delta}+\nu_{t+1}(1-\tilde{\delta})\right\} \\
\lambda_t &= E_t\left\{\lambda_{t+1}\left[1+\theta_{t+1}r_{t+1}(1-\tau_{t+1})+(1-\theta_{t+1})r^e_{t+1}+\Psi\theta^{\psi}_{t+1}\right]\right\}.
\end{aligned}$$

Using the assumptions listed above ($l_{t+1}=l$, $r_{t+1}=r^e_{t+1}=r$, $\tilde{\delta}=\delta$, $\kappa_t=\kappa$, $\chi_t=0$, $\theta_t=\theta$, and $\Psi=0$),

$$\begin{aligned}
\lambda_t(1-\tau_t\kappa) &= \mu_t+(1-\kappa)\nu_t \\
\mu_t &= E_t\left\{\lambda_{t+1}(1-\tau_{t+1})A\frac{\partial f(k_{t+1},l)}{\partial k_{t+1}}+\mu_{t+1}(1-\delta)\right\} \\
\nu_t &= E_t\left\{\lambda_{t+1}\tau_{t+1}\delta+\nu_{t+1}(1-\delta)\right\} \\
\lambda_t &= E_t\left\{\lambda_{t+1}\left[1+r(1-\theta\tau_{t+1})\right]\right\}.
\end{aligned}$$

Substituting the expressions for μ_t and ν_t from the second and third equations into the first one,

$$\begin{aligned}
\lambda_t(1-\tau_t\kappa) &= E_t\left\{\lambda_{t+1}(1-\tau_{t+1})A\frac{\partial f(k_{t+1},l)}{\partial k_{t+1}}+\mu_{t+1}(1-\delta)\right\}+(1-\kappa)E_t\left\{\lambda_{t+1}\tau_{t+1}\delta+\nu_{t+1}(1-\delta)\right\} \\
&= E_t\left\{\lambda_{t+1}(1-\tau_{t+1})A\frac{\partial f(k_{t+1},l)}{\partial k_{t+1}}+\mu_{t+1}(1-\delta)+(1-\kappa)\lambda_{t+1}\tau_{t+1}\delta+(1-\kappa)\nu_{t+1}(1-\delta)\right\} \\
&= E_t\left\{\lambda_{t+1}(1-\tau_{t+1})A\frac{\partial f(k_{t+1},l)}{\partial k_{t+1}}+(1-\kappa)\lambda_{t+1}\tau_{t+1}\delta+\lambda_{t+1}(1-\tau_{t+1}\kappa)(1-\delta)\right\}
\end{aligned}$$

where the last step used the first equation, again, evaluated at $t+1$ rather than t.

Substituting the expression for λ_t from the last equation,

$$\begin{aligned}
&E_t\left\{\lambda_{t+1}\left[1+r(1-\theta\tau_{t+1})\right]\right\}(1-\tau_t\kappa)= \\
&E_t\left\{\lambda_{t+1}(1-\tau_{t+1})A\frac{\partial f(k_{t+1},l)}{\partial k_{t+1}}+(1-\kappa)\lambda_{t+1}\tau_{t+1}\delta+\lambda_{t+1}(1-\tau_{t+1}\kappa)(1-\delta)\right\}.
\end{aligned}$$

In the steady state, $\tau_{t+1}=\tau_t=\tau$, $k_{t+1}=k$, and we can drop the expectation operators:

$$
\begin{aligned}
[1 + r(1 - \theta\tau)]\,(1 - \tau\kappa) &= (1 - \tau)A\frac{\partial f(k,l)}{\partial k} + (1 - \kappa)\tau\delta + (1 - \tau\kappa)(1 - \delta) \\
(1 - \tau\kappa) + r(1 - \theta\tau)(1 - \tau\kappa) &= (1 - \tau)A\frac{\partial f(k,l)}{\partial k} + \tau\delta - \kappa\tau\delta + (1 - \tau\kappa) - \delta + \tau\kappa\delta \\
r(1 - \theta\tau)(1 - \tau\kappa) &= (1 - \tau)A\frac{\partial f(k,l)}{\partial k} - (1 - \tau)\delta \\
\frac{r(1 - \theta\tau)(1 - \tau\kappa)}{1 - \tau} &= A\frac{\partial f(k,l)}{\partial k} - \delta. \qquad (44)
\end{aligned}
$$

The last equation shows how the steady-state capital k responds to a permanent change in the tax rate τ, depending on the debt share θ and the expensing fraction κ. The right-hand side is a decreasing function of k because the marginal product of capital is decreasing. Hence, capital increases (/decreases) in response to an increase in the tax rate if the left-hand side is a decreasing (/increasing) function of τ. Equivalently, capital increases (/decreases) in response to an increase in the tax rate if the derivative of the left-hand side with respect to τ is negative (/positive).

The derivative of the left-hand side of (44) with respect to τ is

$$
\begin{aligned}
LHS_\tau &= r\frac{(1 - \tau)\,[-\theta(1 - \tau\kappa) - \kappa(1 - \theta\tau)] + (1 - \theta\tau)(1 - \tau\kappa)}{(1 - \tau)^2} \\
LHS_\tau &= r\frac{-\theta(1 - \tau)(1 - \tau\kappa) - \kappa(1 - \tau)(1 - \theta\tau) + (1 - \theta\tau)(1 - \tau\kappa)}{(1 - \tau)^2}.
\end{aligned}
$$

First, let us study how the derivative changes as θ changes, for given $\kappa \in (0, 1)$. The derivative can be written as

$$
\begin{aligned}
LHS_\tau &= r\frac{-\theta(1 - \tau)(1 - \tau\kappa) - (\kappa - \tau\kappa)(1 - \theta\tau) + (1 - \theta\tau)(1 - \tau\kappa)}{(1 - \tau)^2} \\
LHS_\tau &= r\frac{-\theta(1 - \tau)(1 - \tau\kappa) + (1 - \theta\tau)(1 - \kappa)}{(1 - \tau)^2}.
\end{aligned}
$$

The derivative is positive for $\theta = 0$, decreases with θ, and is negative for $\theta = 1$:

$$
\begin{aligned}
LHS_\tau|_{\theta=0} &= r\frac{(1 - \kappa)}{(1 - \tau)^2} > 0 \\
\frac{\partial LHS_\tau}{\partial \theta} &= r\frac{-(1 - \tau)(1 - \tau\kappa) - \tau(1 - \kappa)}{(1 - \tau)^2} < 0 \\
LHS_\tau|_{\theta=1} &= r\frac{-(1 - \tau)(1 - \tau\kappa) + (1 - \tau)(1 - \kappa)}{(1 - \tau)^2} = r\frac{-1 + \tau\kappa + 1 - \kappa}{1 - \tau} = -r\kappa < 0.
\end{aligned}
$$

Hence, for small values of θ (when investment is mainly financed through equity), the left-hand side of (44) is increasing in τ, capital k is decreasing in τ, and a tax cut stimulates investment. Vice versa, a tax cut discourages investment for large values of θ (when investment is mainly financed through debt).

Next, let us study how the derivative changes as κ changes, for given $\theta \in (0,1)$. The steps are analogous to the ones just used to study how the derivative changes as θ changes. The derivative can be written as

$$\begin{aligned} LHS_\tau &= r\frac{-(\theta-\tau\theta)(1-\tau\kappa)-\kappa(1-\tau)(1-\theta\tau)+(1-\theta\tau)(1-\tau\kappa)}{(1-\tau)^2} \\ LHS_\tau &= r\frac{-\kappa(1-\tau)(1-\theta\tau)+(1-\theta)(1-\tau\kappa)}{(1-\tau)^2}. \end{aligned}$$

The derivative is positive for $\kappa = 0$, decreases with κ, and is negative for $\kappa = 1$:

$$\begin{aligned} LHS_\tau|_{\kappa=0} &= r\frac{(1-\theta)}{(1-\tau)^2} > 0 \\ \frac{\partial LHS_\tau}{\partial\kappa} &= r\frac{-(1-\tau)(1-\theta\tau)-\tau(1-\theta)}{(1-\tau)^2} < 0 \\ LHS_\tau|_{\kappa=1} &= r\frac{-(1-\tau)(1-\theta\tau)+(1-\theta)(1-\tau)}{(1-\tau)^2} = r\frac{-1+\theta\tau+1-\theta}{1-\tau} = -r\theta < 0. \end{aligned}$$

Hence, for small values of κ (when most investment expenses cannot be deducted immediately and capital depreciation is slow), the left-hand side of (44) is increasing in τ, capital k is decreasing in τ, and a tax cut stimulates investment. Vice versa, a tax cut discourages investment for large values of κ (when most investment expenses can be deducted immediately and capital depreciation is fast).

	Description	Value	Targeted moments and notes
β	bus. owner pref. discount factor	0.963	implied by r and tax rates
$\tilde{\beta}$	household pref. discount factor	0.967	implied by r and tax rates
γ	relative risk aversion	2	
φ	Frisch elasticity of labor supply	0.5	
Φ	labor disutility parameter	23.04	$l = n = 1/3$
r	real interest rate	0.04	
w	real wage rate	1.51	
α	production function exponent	0.33	
δ	economic depreciation rate	0.1	
Y	GDP	1	normalized
A	production function scale	1.30	$y = 0.75$ (GDP share of bus. output)
y^H	household endowment	0.125	GDP share of private non-bus. output
y^G	govt. endowment	0.125	GDP share of govt. output
τ	bus. income tax rate	0.35	pre-2017 corporate tax rate
ρ_τ	bus. income tax rate autocorr.	1	
κ	investment expensing fraction	0.48	partial bonus depreciation
ρ_κ	investment expensing autocorr.	1	
$\tilde{\delta}$	tax depreciation rate	0.2	$\tilde{\delta} = 2\delta$ (accelerated depreciation)
χ	investment tax credit fraction	0.01	R&D tax credit
ρ_χ	investment tax credit autocorr.	1	
I	bus. taxable income	0.0624	
X	bus. tax liability	0.0201	
τ^w	labor income tax rate	0.29	effective marginal tax rate
τ^r	capital income tax rate	0.15	capital gain tax rate
τ^d	dividend tax rate	0.15	dividend tax rate
τ^c	consumption tax rate	0.06	sales tax rate
T	govt. tax revenue	0.217	
θ	debt share of financial capital	0.21	corporate debt and equity
a	bus. financial capital	1.3	equal to firm's value
b	debt	0.273	
E	total equity	1.03	
v	inside equity	0.513	
e	outside equity	0.513	
ψ	financial distress costs exponent	0.475	elasticity of θ to τ
Ψ	financial distress costs scale	0.121	$w(\theta)a = 0.0012$
G	govt. spending	0.18	GDP share of govt. spending
Z	govt. lump-sum transfers	0.131	$B = 0.76$ (govt. debt as percent of GDP)
C	aggregate consumption	0.645	$c = 0.0165$, $\tilde{c} = 0.628$
x	investment	0.174	
k	economic capital	1.74	
$\tilde{k}$	tax capital	0.453	

Table 1: Parameters and steady-state values. *Note: The length of a period is 1 year.*

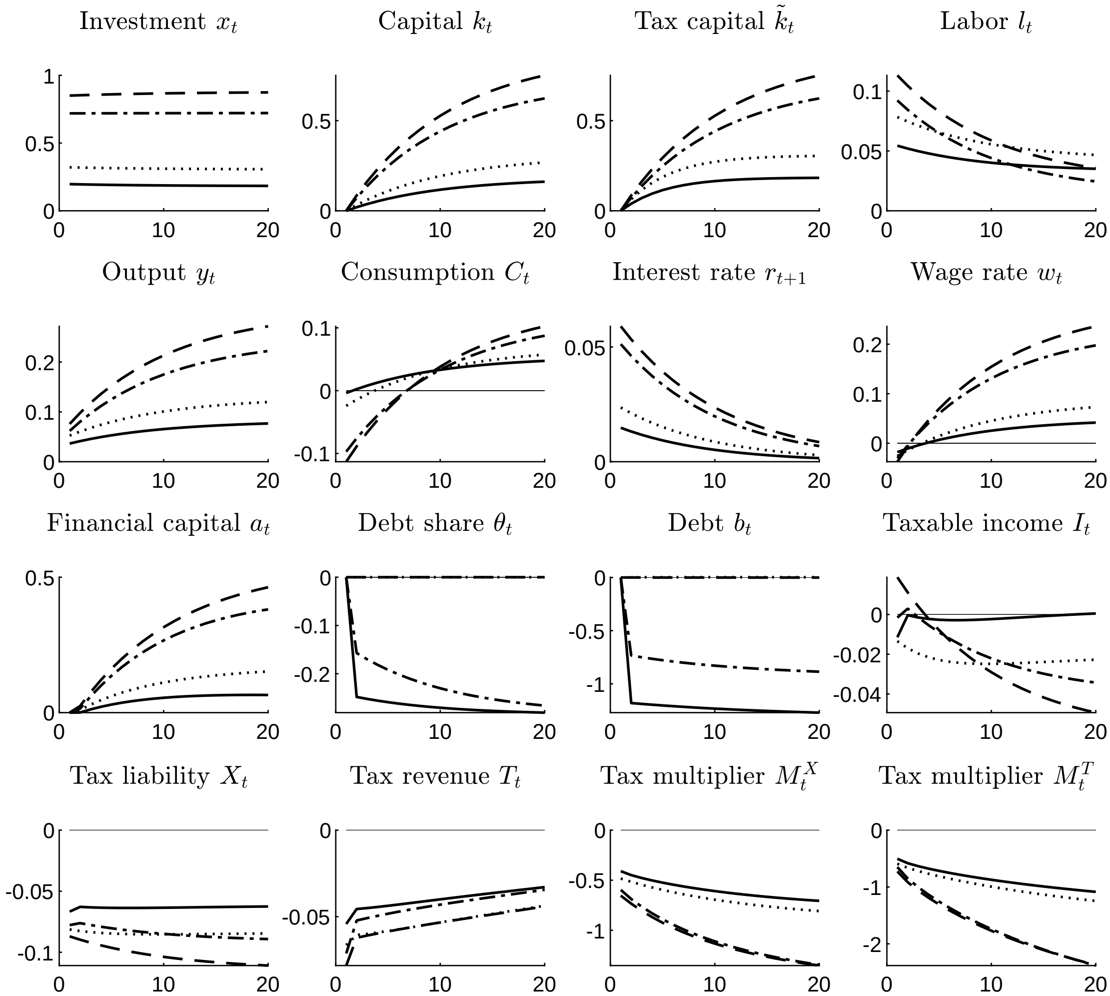

Figure 1: Effect of a permanent cut in the business income tax rate, τ_t. The role played by debt financing and accelerated depreciation. *Notes: The dashed line refers to an economy without debt and accelerated depreciation ($\theta = 0$, $\kappa = 0$, and $\tilde{\delta} = \delta = 0.1$), while the dashed-dotted line refers to the same economy with debt ($\theta = 0.21$, $\kappa = 0$, and $\tilde{\delta} = \delta = 0.1$). The solid line refers to the baseline economy ($\theta = 0.21$, $\kappa = 0.48$, and $\tilde{\delta} = 0.2$), while the dotted line refers to the same economy without debt ($\theta = 0$, $\kappa = 0.48$, and $\tilde{\delta} = 0.2$). The size of the tax cut is 1. The responses of x_t, k_t, $\tilde{k}_t$, l_t, y_t, C_t, w_t, a_t, and b_t are divided by their respective steady-state values.*

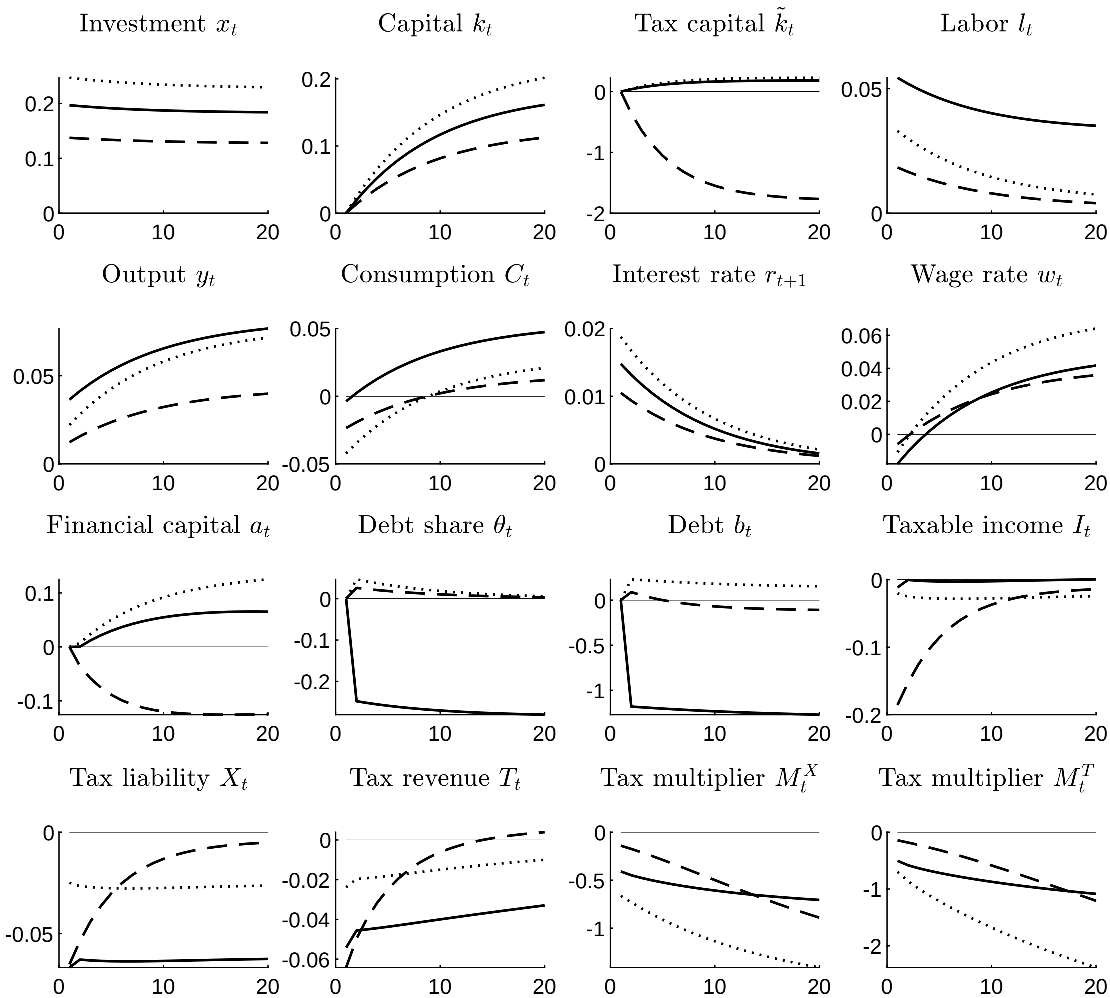

Figure 2: Effect of permanent tax policy changes. *Notes: The solid, dashed, and dotted lines refer, respectively, to the effect of a cut in the business income tax rate,* τ_t*, the effect of an increase in the investment expensing fraction,* κ_t*, and the effect of an increase in the investment tax credit,* χ_t*. The size of the first two shocks is 1, while the size of the third shock is 0.1. The responses of* x_t*,* k_t*,* $\tilde{k}_t$*,* l_t*,* y_t*,* C_t*,* w_t*,* a_t*, and* b_t *are divided by their respective steady-state values.*

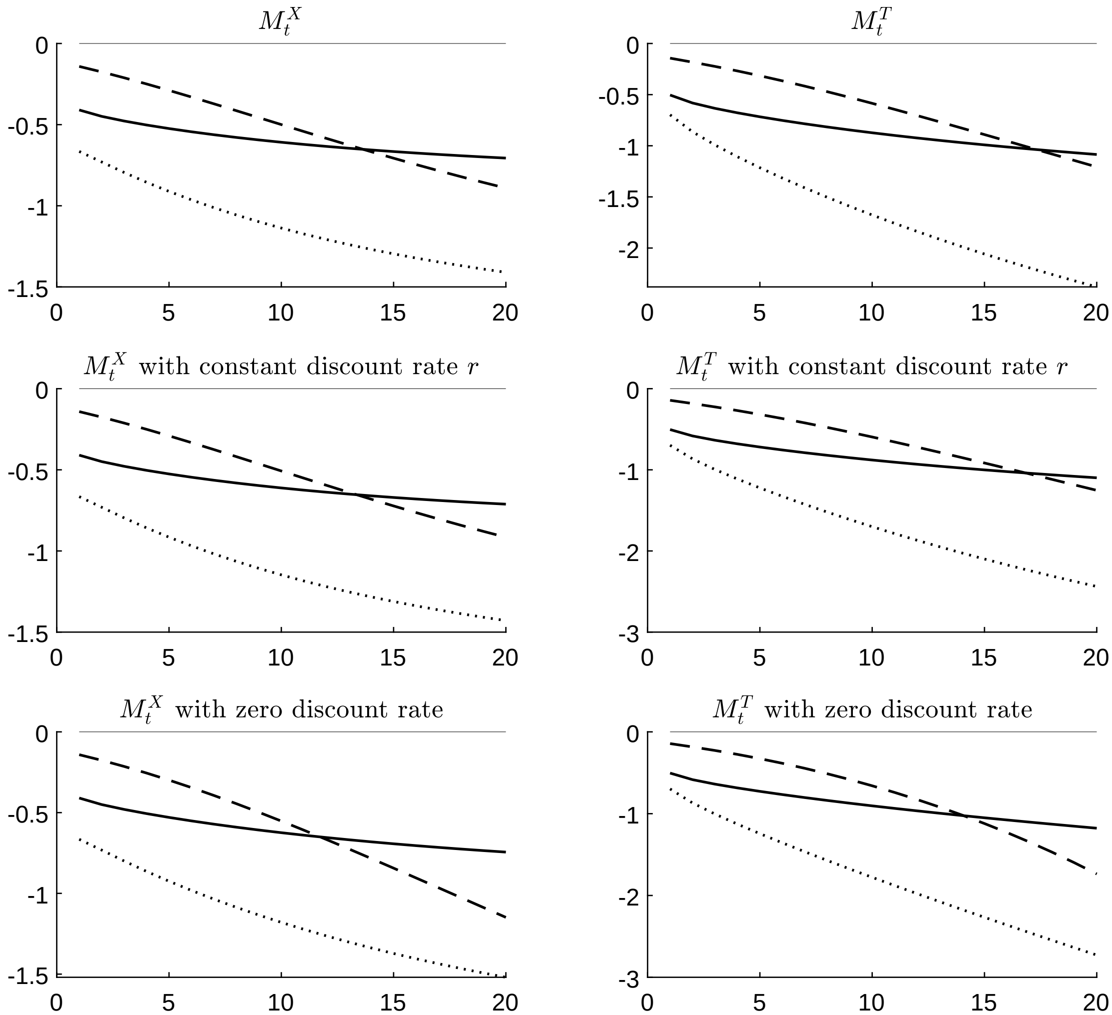

Figure 3: Cumulative tax multipliers. *Notes: The solid, dashed, and dotted lines refer, respectively, to the cumulative tax multiplier of the business income tax rate, τ_t, the investment expensing fraction, κ_t, and the investment tax credit, χ_t.*

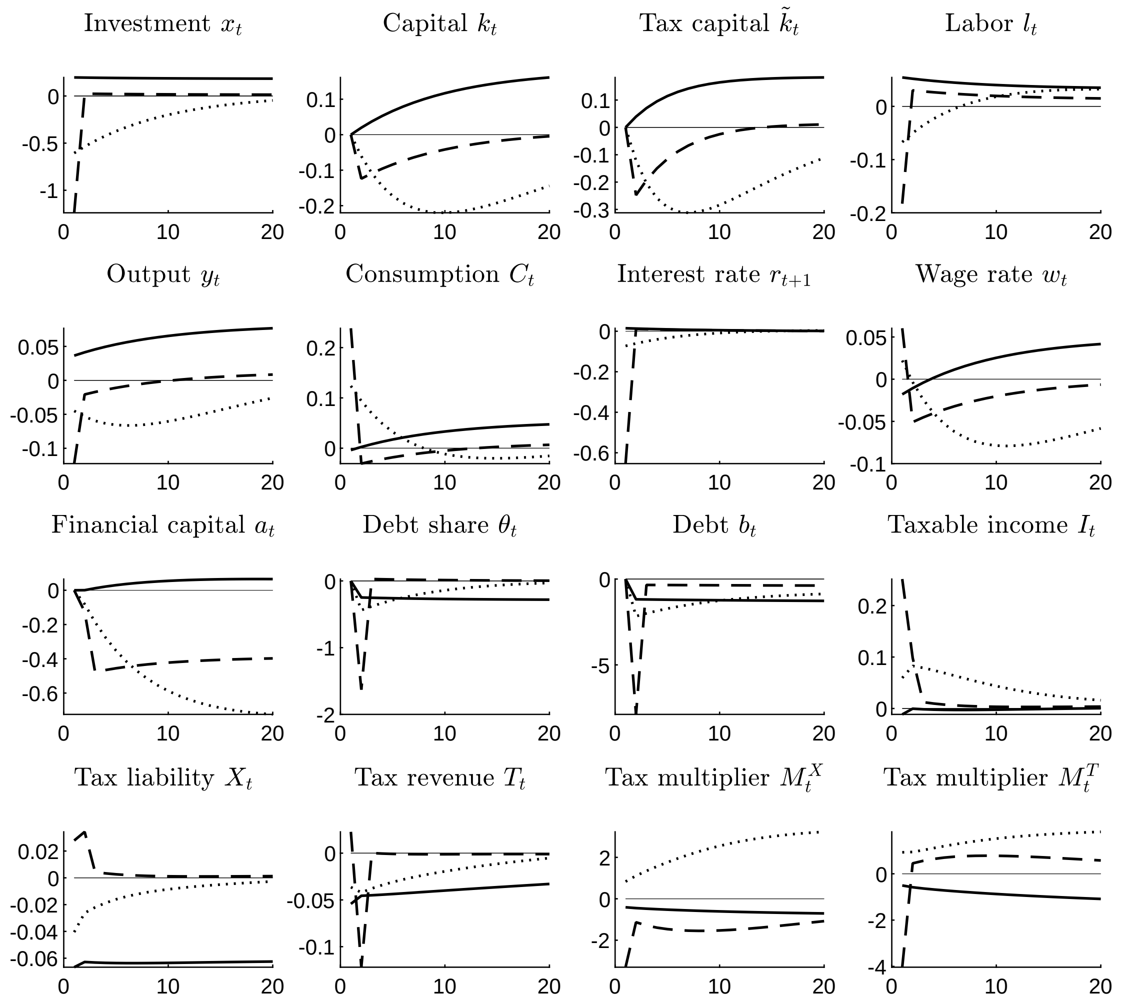

Figure 4: Effect of permanent versus temporary cuts in the business income tax rate, τ_t. *Notes: The dashed, dotted, and solid lines refer, respectively, to* $\rho_\tau = 0$, $\rho_\tau = 0.9$, *and* $\rho_\tau = 1$ *(the baseline value).*

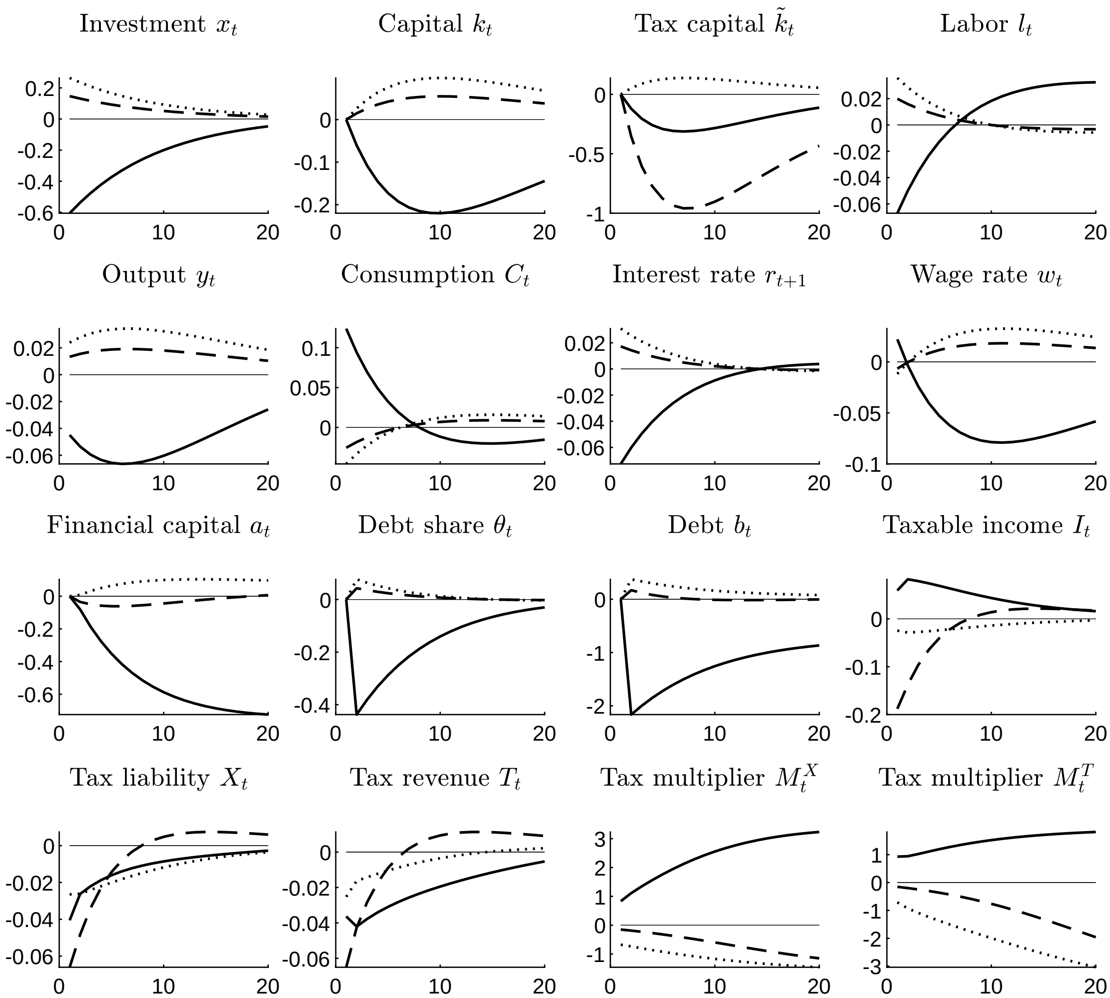

Figure 5: Effect of temporary tax policy changes. *Notes: The solid, dashed, and dotted lines refer, respectively, to the effect of a cut in the business income tax rate, τ_t, the effect of an increase in the investment expensing fraction, κ_t, and the effect of an increase in the investment tax credit, χ_t. The size of the first two shocks is 1, while the size of the third shock is 0.1. For all three policy variables, the first-order autocorrelation is 0.9.*

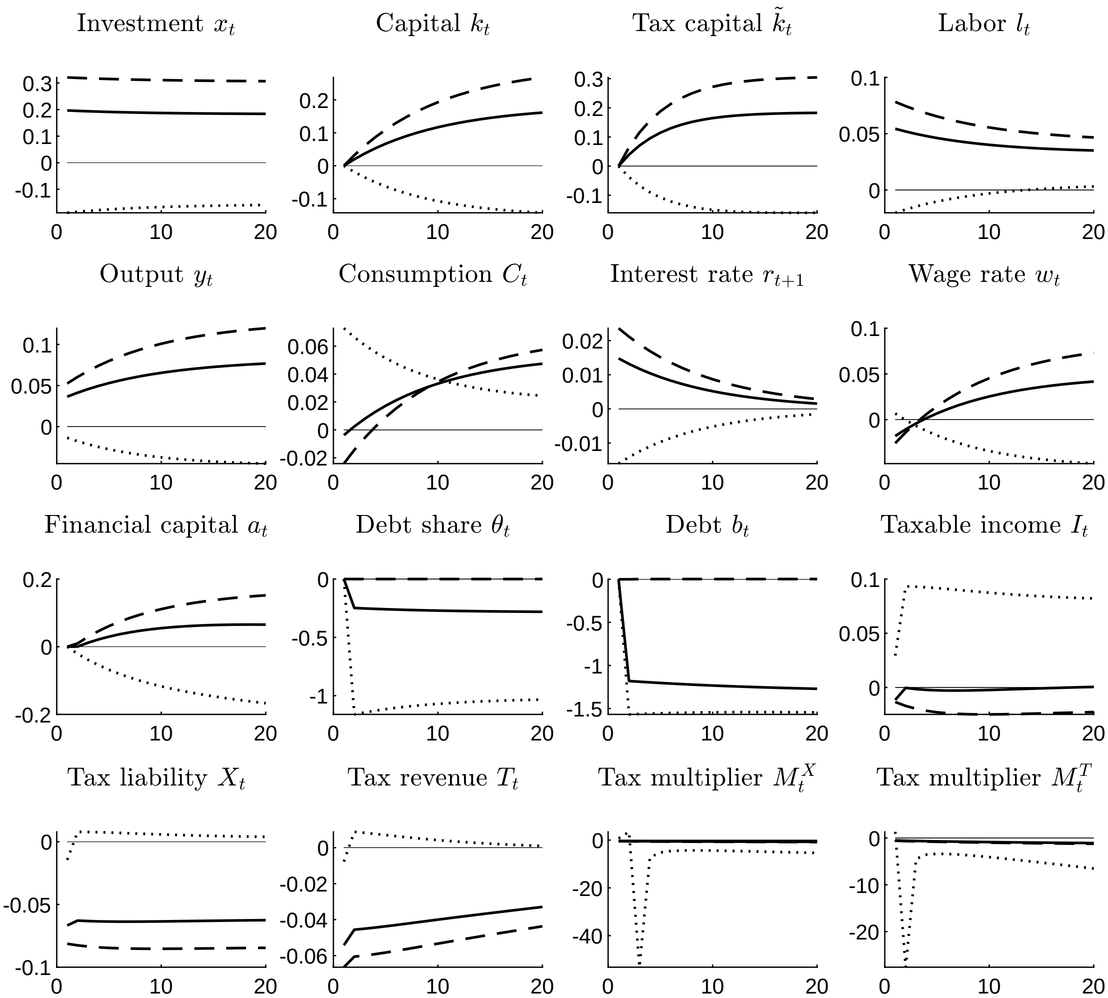

Figure 6: Effect of a permanent tax cut. Sensitivity to the steady-state debt share, θ. *Notes: The dashed, solid, and dotted lines refer, respectively, to* $\theta = 0$, $\theta = 0.21$ *(the baseline value), and* $\theta = 0.75$.

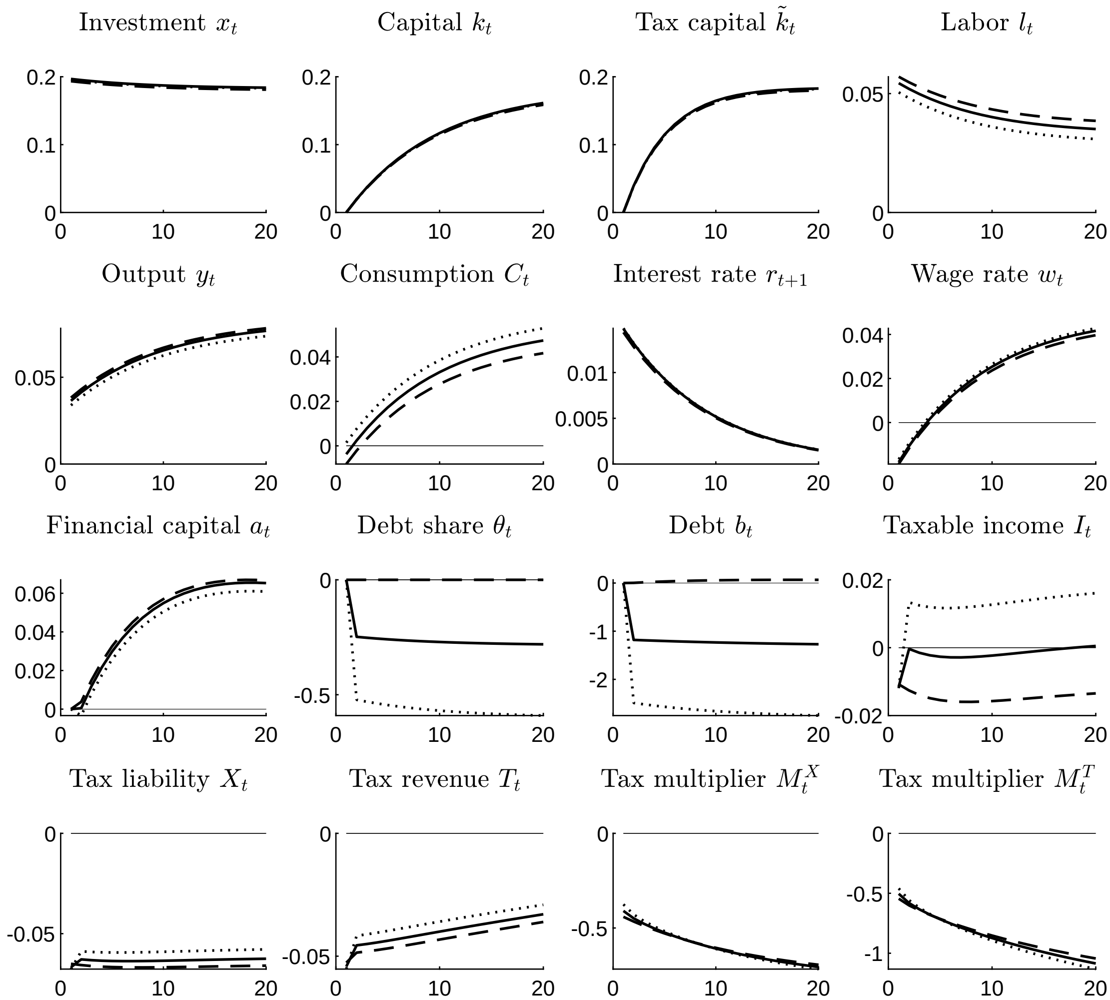

Figure 7: Effect of a permanent tax cut. Sensitivity to the elasticity, ψ, of the debt share to the tax rate. *Notes: The dashed line refers to the economy where the debt share, θ_t, is constant ($\psi \to 0$), while the solid and dotted lines refer, respectively, to $\psi = 0.475$ (the baseline value) and $\psi = 1$.*

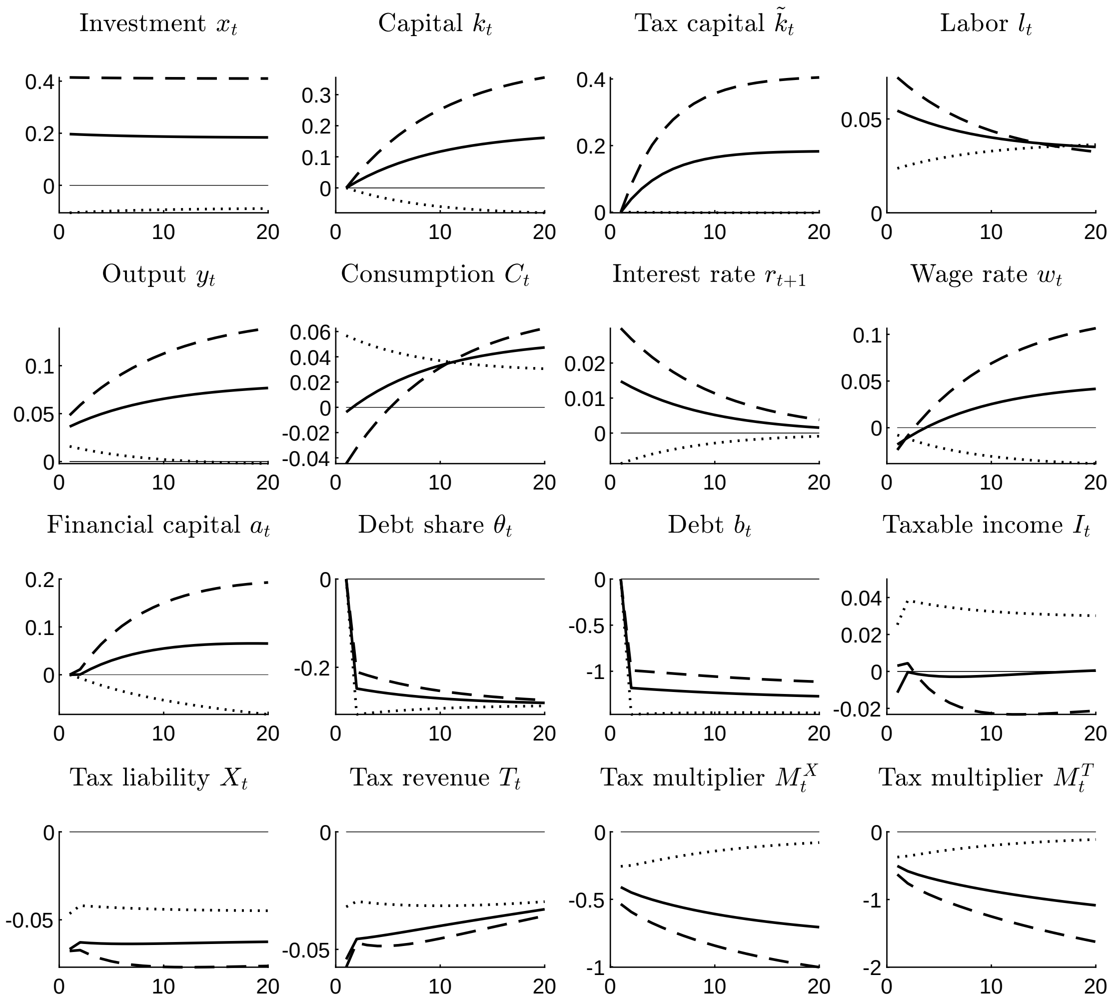

Figure 8: Effect of a permanent tax cut. Sensitivity to the investment expensing fraction, κ. *Notes: The dashed, solid, and dotted lines refer, respectively, to* $\kappa = 0$, $\kappa = 0.48$ *(the baseline value), and* $\kappa = 1$.

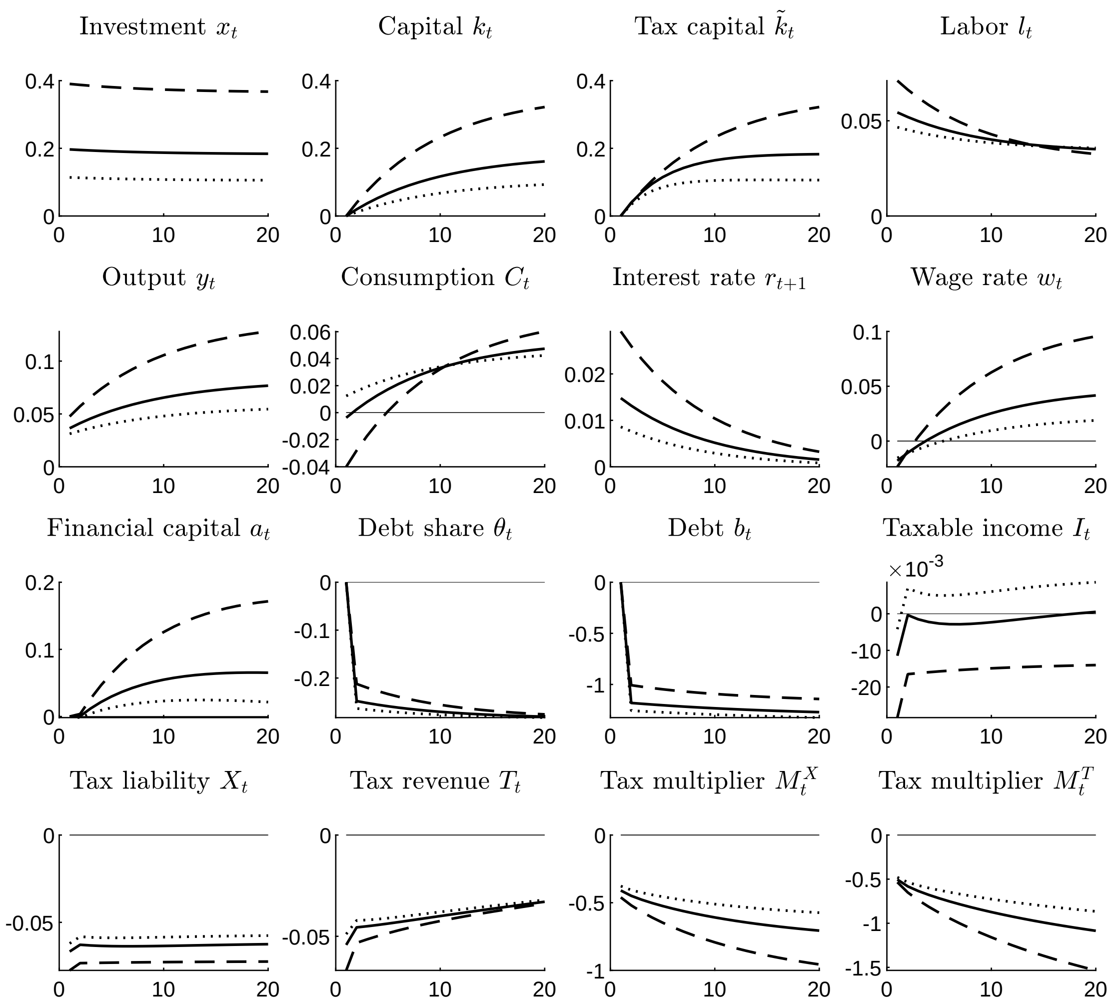

Figure 9: Effect of a permanent tax cut. Sensitivity to the tax depreciation rate, $\tilde{\delta}$.

Notes: The dashed, solid, and dotted lines refer, respectively, to $\tilde{\delta} = 0.1$, $\tilde{\delta} = 0.2$ *(the baseline value), and* $\tilde{\delta} = 0.3$.

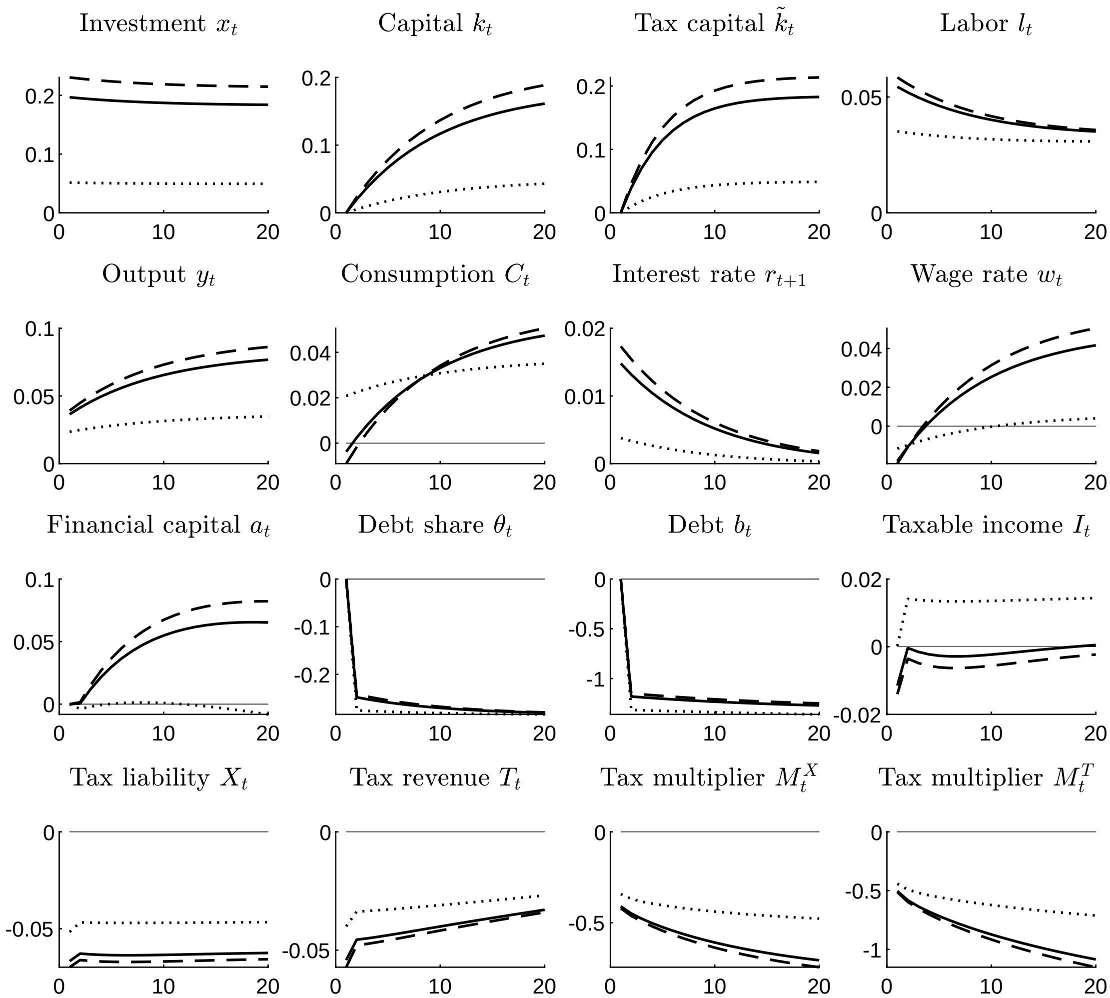

Figure 10: Effect of a permanent tax cut. Sensitivity to the investment tax credit, χ. *Notes: The dashed, solid, and dotted lines refer, respectively, to* $\chi = 0$, $\chi = 0.01$ *(the baseline value), and* $\chi = 0.05$.

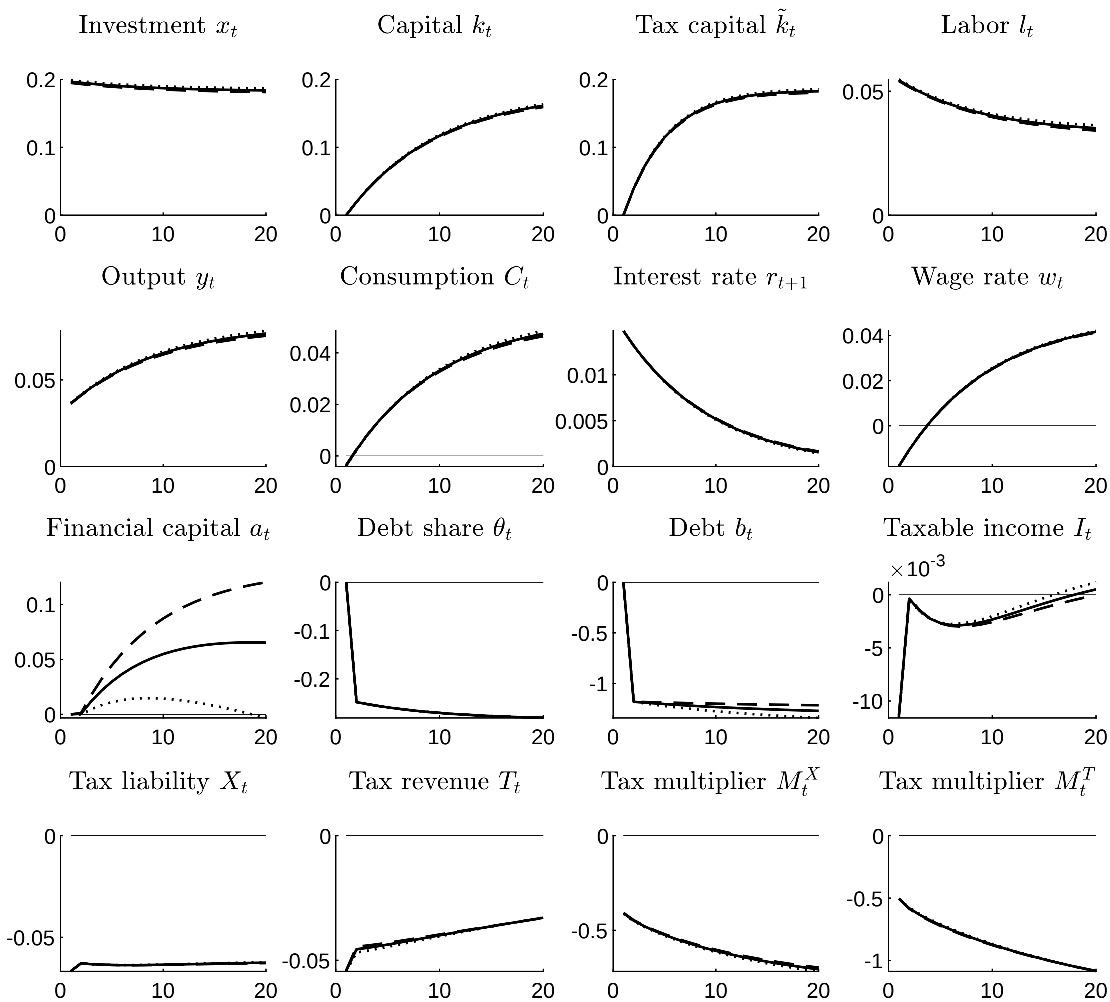

Figure 11: Effect of a permanent tax cut. Sensitivity to inside equity, v. *Notes: The dashed, solid, and dotted lines refer, respectively, to $v = 0.1 \times E$, $v = 0.5 \times E$ (the baseline value), and $v = E$.*

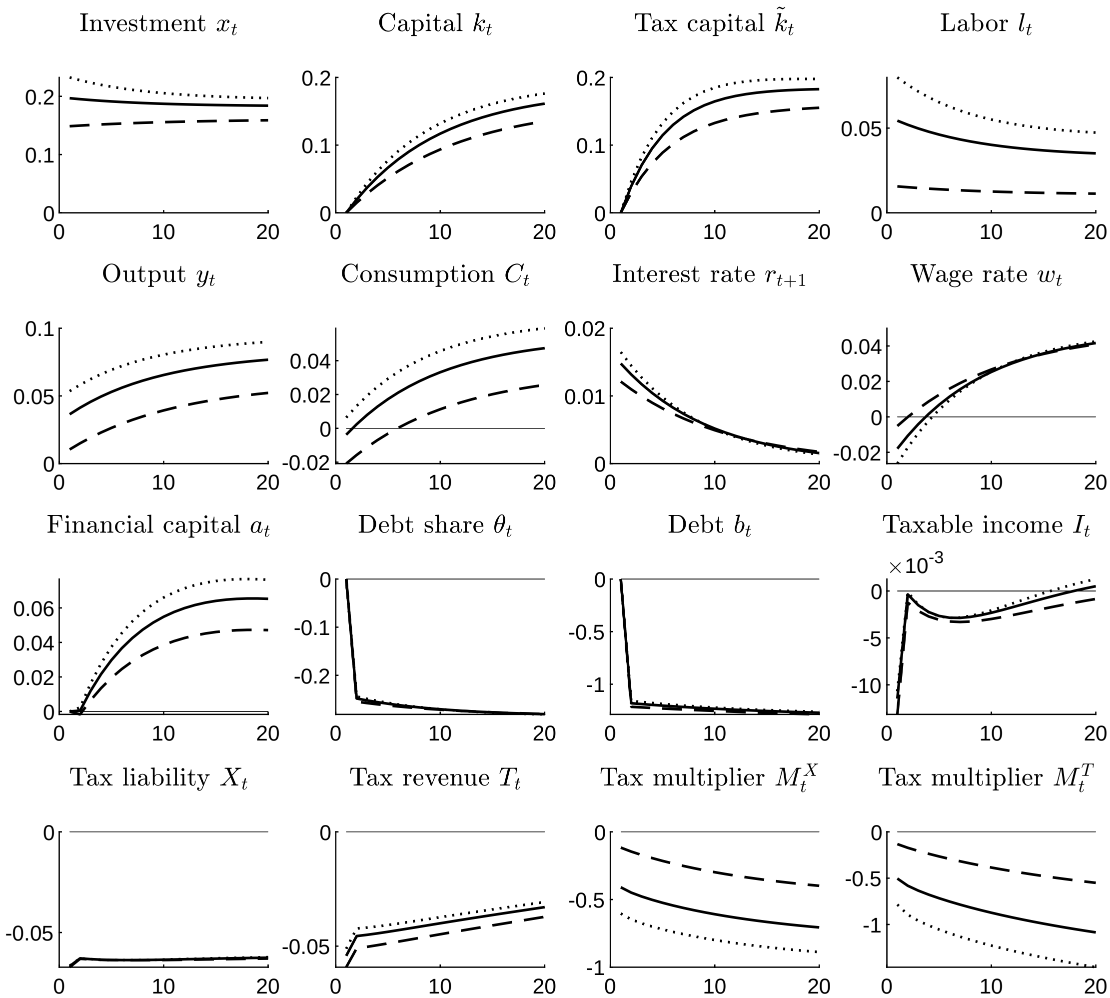

Figure 12: Effect of a permanent tax cut. Sensitivity to the Frisch elasticity of labor supply, φ. *Notes: The dashed, solid, and dotted lines refer, respectively, to* $\varphi = 0.1$, $\varphi = 0.5$ *(the baseline value), and* $\varphi = 1$.

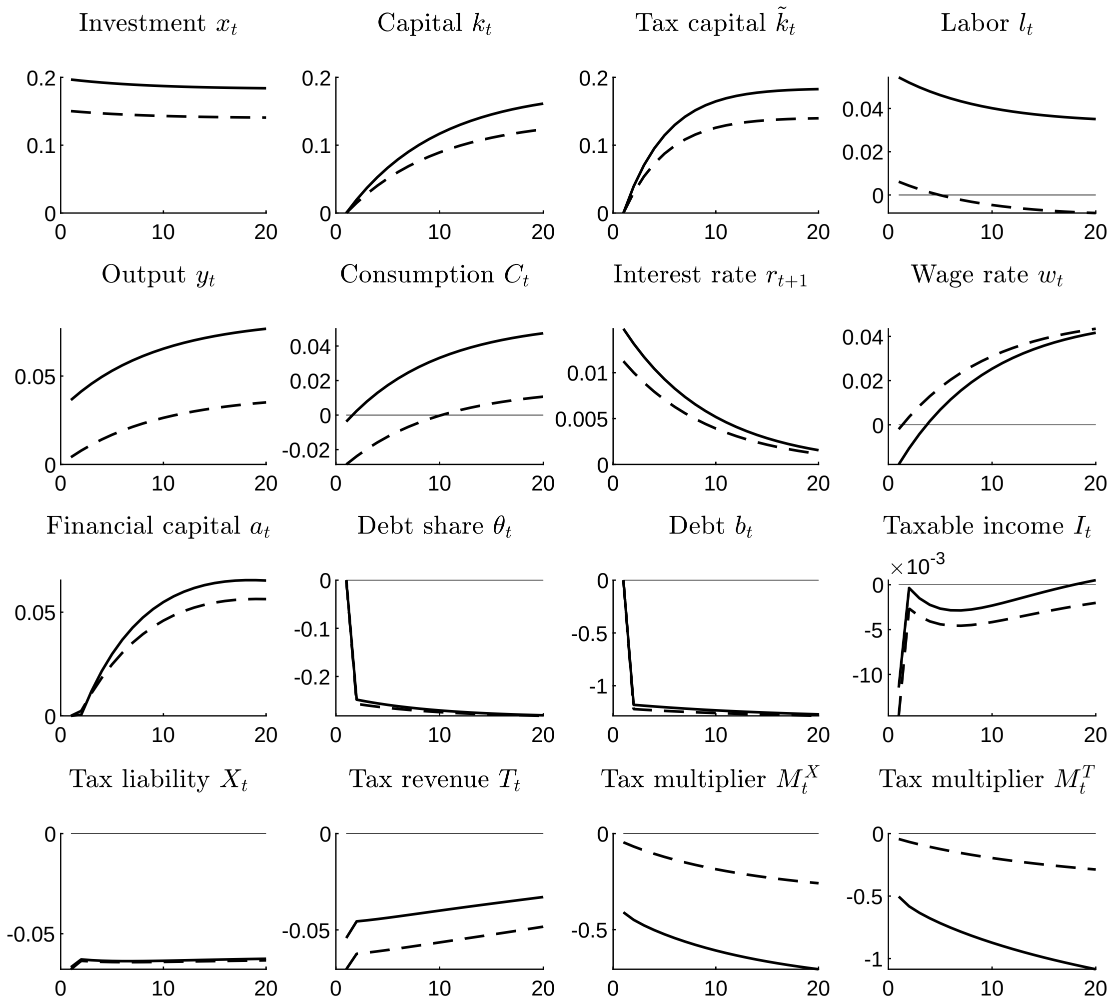

Figure 13: Effect of a permanent tax cut. Sensitivity to the financing of the tax cut.

Notes: The solid line refers to the baseline economy where the tax cut is financed by future cuts in the government transfers to households, while the dashed line refers to an economy where the tax cut is financed by lump-sum taxes levied on businesses.