General-Equilibrium Effects of Investment Tax Incentives

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Abstract

This paper uses a dynamic general-equilibrium model with a nominal tax system to consider the effects of a temporary tax-based investment incentive (a partial expensing allowance) on capital spending and other macroeconomic aggregates.

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1 Introduction

The past two U.S. recessions have seen the enactment of sizeable fiscal stimulus packages. In each case, these packages have included significant provisions for temporary partial expensing allowances on business equipment investment.[1] In particular, the 2002 Job Creation and Worker Assistance Act, which went into effect after the 2001 recession, contained a provision for a 30 percent expensing allowance for investment undertaken between September 11, 2001 and September 10, 2004.[2] Similarly, in the most recent recession the 2008 Economic Stimulus Act provided for a 50 percent expensing allowance for investment spending undertaken during the 2008 calendar year.

Despite the increased reliance on temporary expensing allowances as an instrument of countercyclical fiscal policy, to date essentially no attempt has been made to assess the impact of these provisions in a fully specified structural forward-looking general-equilibrium model—particularly the new-Keynesian framework that, for better or for worse, now serves as the workhorse specification for analyzing macroeconomic stabilization policies. This situation is somewhat ironic when we consider that one of the earliest calls for a structural approach to policy modelling—Lucas's 1976 paper "Econometric Policy Evaluation: A Critique"—specifically invoked the example of an investment tax incentive to make its point. It is also somewhat surprising given that an analysis of a temporary expensing allowance would seem to provide an excellent candidate for this kind of approach: There is significant scope for the general- equilibrium effects of these policies to differ from what a partial-equilibrium analysis would predict; moreover, that fact that these tax changes are temporary requires us to explicitly consider how agents' behavior today is affected by their expectations of future events.[3]

[1]Partial expensing allowances—also known as bonus depreciation allowances—permit firms to deduct a fraction of the cost of newly purchased capital goods from their taxable income. An expensing allowance is therefore similar to an investment tax credit (ITC) in that it allows a firm to raise its posttax income through purchases of capital goods; importantly, however, a firm is not allowed to claim any future depreciation allowances for its expensed capital (under an ITC, such a restriction is partly or wholly absent).

[2]In the 2003 Jobs and Growth Tax Relief Reconciliation Act, the allowance was raised to 50 percent and extended to December 31, 2004.

[3]Previous analyses of investment tax policies have not employed a framework that permits the simultaneous treatment of these issues. For example, Elmendorf and Reifschneider (2003) use

In this paper, we incorporate a nominal tax system with depreciation allowances into an otherwise- standard new-Keynesian model, and use the resulting setup to analyze the effect of a temporary partial expensing allowance on investment and real activity. We find that the new-Keynesian features of the model have an important influence on the magnitude of the economy's response to a temporary investment incentive; in particular, with sticky prices and wages it is possible for the effects of a temporary expensing allowance on investment to be *larger* in general equilibrium than they are in partial equilibrium. This result contradicts the conventional view that partial-equilibrium calculations overstate the effect that temporary tax incentives will have on investment (a view that has largely been derived from analyses that employ neoclassical models).

We then use our model to explore two practical policy questions associated with partial expensing allowances. First, we examine a claim made by Christiano (1984) that the use of temporary tax incentives on investment can be destabilizing. The intuition behind Christiano's argument is that if agents come to expect that such incentives will be put into place whenever the economy enters a recession, they will postpone their capital expenditures (thereby weakening the economy further) until the incentives are actually enacted. We conclude that this result hinges on how the model is specified—in particular, on the form that capital and/or investment adjustment costs take. Next, we look at the relative effects of two types of tax-based investment incentives: temporary partial expensing, and temporary reductions in the capital tax rate. Here we find—consistent with previous research—that temporary partial expensing allowances provide much more stimulus to investment and real activity than do temporary capital tax cuts (when both policies are set so as to result in the same revenue reductions for the government).

An important incidental contribution of our analysis is the insight that it gives

a forward-looking macromodel (the Federal Reserve's FRB/US model) to examine the effect of a *permanent* investment tax incentive (specifically, an investment tax credit), but are unable to analyze the effect of a temporary credit. Likewise, House and Shapiro (2006) use a simple general-equilibrium setup to look at the effect of a temporary bonus depreciation allowance; however, they do not consider rational-expectations solutions to their model, but instead use an approximation whereby future expectations of a variable are set equal to the variable's steady-state value (the model is also fully neoclassical, with no nominal rigidities). Other analyses have assessed the impact of investment tax incentives in a partial-equilibrium context; see, for instance, Abel (1982) and Cohen, Hansen, and Hassett (2002).

into how the canonical new-Keynesian model responds to an important class of *fiscal* policies. Previous research has provided us with a relatively broad understanding of the model's strengths and shortcomings as a tool for monetary policy evaluation. However, the model's successes (or failures) in illuminating monetary policy issues need not translate to a corresponding degree of success in the fiscal policy context. In particular, this focus on monetary policy (as well as these models' inherent complexity) has often led researchers to place less emphasis on capturing features of the economy—such as the capital-formation process—that are likely to matter much more when fiscal policy concerns are paramount. We therefore provide a relatively detailed description of how the model responds to the particular fiscal policy changes we consider, and identify those components of the model's structure that most profoundly influence our results.

The balance of the paper is organized as follows. Section 2 derives the model used in the paper, which—outside of its treatment of investment and the tax system—is broadly similar to other new-Keynesian specifications. Section 3 then uses the model to study the effects of a partial expensing allowance on capital expenditures and the macroeconomy. Section 4 examines whether the consistent use of a temporary partial expensing allowance as a countercyclical stabilization tool can itself be destabilizing, while section 5 compares the relative "bang-for-the-buck" of partial expensing and reductions in the capital tax rate. Finally, section 6 concludes.

2 A New-Keynesian Model with Nominal Taxation

Our model economy is characterized by three sets of agents: households, firms, and the government. A continuum of households consume output, supply labor (over which they have monopolistically competitive wage-setting power), and purchase goods that are then transformed into capital and rented to firms. There are two classes of firms: a continuum of monopolistically competitive intermediate-goods producers, each of whom hires capital and all differentiated types of labor to produce a differentiated good, and a single final-good producer who aggregates the intermediate goods to produce output for final demand. Finally, the government consists of a fiscal authority, who levies taxes that are rebated to households as lump-sum transfers, and a monetary authority who sets interest rates according to a Taylor rule.

With the exception of our treatment of taxation and investment, our theoretical setup is quite similar to the sticky-price monetary business cycle models used by Woodford (2003) and others to analyze monetary policy. We therefore devote most of this section to a detailed examination of those features of the model that are affected by the introduction of a nominal tax system.

2.1 Households

The preferences of household i (where $i \in [0,1]$) are represented by the utility function

$$U_0 = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{1-\sigma} \left(C_t^i \right)^{1-\sigma} - \frac{1}{1+s} \left(H_t^i \right)^{1+s} \right] \right\}, \tag{1}$$

where C_t^i is defined as household i's consumption, H_t^i is its differentiated labor supply, and β and s denote the household's discount factor and labor supply elasticity, respectively.

The household's budget constraint—which reflects its role in accumulating physical capital—is given by

$$\begin{aligned} A_{t+1}^i / R_t^f = {} & A_t^i + R_t^k K_t^i - F_t^k \left(R_t^k K_t^i - X_t P_t I_t^i - \sum_{v=1}^{\infty} \delta (1-\delta)^{v-1} \left(1 - X_{t-v}\right) P_{t-v} I_{t-v}^i \right) \\ & + \left(1 - F_t^h\right) \left(W_t^i H_t^i + \mathit{Profits}_t^i \right) + T_t^i - P_t C_t^i - P_t I_t^i, \end{aligned} \tag{2}$$

where

$$R_t^f = R_t - F_t^h \left(R_t - 1 \right). \tag{3}$$

The variable A_t^i denotes the nominal value of household i's bond holdings at the beginning of period t; W_t^i is the nominal wage paid on labor; R_t^k is the rental rate paid to household i for the use of its capital stock K_t^i (where K_t^i depreciates geometrically at the rate δ); $\mathit{Profits}^i$ represents the profits disbursed (as dividends) to households from the monopolistically competitive intermediate-goods producers; T_t^i are lump-sum transfers from the fiscal authority; P_t is the price of final output; I_t^i denotes the household's current-period purchases of investment goods; and R_t is the gross *pretax* nominal interest rate between periods t and $t+1$.

The fiscal system that we assume taxes all forms of nominal personal income (that is, income from financial assets, dividends, and labor) at the rate F_t^h, and taxes capital income at the rate F_t^k.[4] Hence, households receive an after-tax return R_t^f on their financial assets that is given by equation (3).[5] In addition, two types of deductions are permitted against capital income: depreciation charges and expensing allowances. The presence of depreciation allowances reflects the fiscal authority's recognition that part of the payment capital owners receive from renting out their capital stock merely reflects compensation for the depreciation of the stock from its use in production. An expensing allowance, meanwhile, represents a (partial) rebate of the purchase price of a new capital good. Unlike a pure subsidy or credit, however, future depreciation of the portion of the new investment good that is expensed may not later be deducted from taxable income. Thus, an expensing allowance can be loosely thought of as a completely "front-loaded" depreciation allowance.

We make the standard simplifying assumption that households directly own all capital in the economy and rent it out to firms.[6] This implies that tax provisions on investment are directly reflected in the budget constraint (2), as follows. First, an expensing allowance X_t is applied to household i's time-t nominal expenditure

[4]We are making an arbitrary (but ultimately unimportant) distinction here between the "profits" that appear in equation (2)—which represent a pure surplus over the payments to the factors of production that is distributed as a dividend to firm owners—and payments to households in their capacity as owners of the capital stock, which serve as the base of the corporate income tax. While it is somewhat artificial to assume that the former payments are not considered profits by the tax code, this assumption has no substantive effect on our analysis because monopoly profits have the same effect on household budget constraints as a lump-sum payment (and are zero in equilibrium).

[5]Note that the form of this expression reflects the fact that only interest—not principal—is subject to taxation.

[6]This assumption makes no substantive difference to our results. In the standard flexible-price framework, there is a well-known parallel between assuming a rental market for capital (as is done here) and directly modelling the firm's investment decision; this is why our first-order conditions for capital investment are equivalent to the usual neoclassical expressions. (Intuitively, the shadow value of capital to the firm will be identical to the user cost that obtains in a rental market.) The problem becomes more complicated when prices are sticky: If firms are investing directly, rather than renting capital from households, then they must make their price-setting and investment decisions simultaneously; the resulting optimization problem is therefore much more complicated. In practice, however, the only effect of assuming direct investment by firms is to raise the effective degree of price stickiness in the economy. Since our results are not importantly affected by the degree of price rigidity that we assume—and since the intuition behind our results is made far clearer by the assumption of a rental market for capital—we take this more straightforward approach in developing our model economy.

on new capital goods, $P_t I_t^i$. Second, the dollar value of depreciation at time-t from all previous purchases of capital is given as $\sum_{v=1}^{\infty} \delta(1-\delta)^{v-1} P_{t-v} I_{t-v}^i$. However, because previously expensed capital may not receive a depreciation allowance, each term $P_{t-v} I_{t-v}^i$ in the sum in equation (2) must be multiplied by $(1 - X_{t-v})$. In addition, under the U.S. tax code depreciation is computed using *historical* cost; as a result, the investment price in the depreciation term is written with a $t - v$ subscript.[7]

In practice, depreciation allowances are based on a legislated schedule of depreciation rates, not the true (economic) depreciation rate δ. In our model, using legislated depreciation rates to compute depreciation allowances would merely involve replacing $\sum_{v=1}^{\infty} \delta(1-\delta)^{v-1} P_{t-v} I_{t-v}^i$ in equation (2) with $\sum_{v=1}^{V} \delta_v^{irs} P_{t-v} I_{t-v}^i$, where V denotes the tax-life of the capital stock—which averages around 5-1/2 years (22 quarters) for equipment investment—and δ_v^{irs} denotes the rate of depreciation for tax purposes (specified by the tax code) in the vth period of the capital stock's life. However, this extension significantly increases the number of state variables in the model, and complicates our interpretation of the resulting first-order conditions for investment. In addition, it turns out that few of the model's qualitative results are affected by our equating tax depreciation with economic depreciation.[8] We therefore assume that $\delta_v^{irs} = \delta(1-\delta)^{v-1}$ throughout.

In the absence of any adjustment costs on capital or investment spending, the capital accumulation process is given by

$$K_{t+1}^i = (1-\delta) K_t^i + I_t^i \exp[\xi_t^i], \tag{4}$$

where ξ_t^i represents a shock to the efficiency of investment spending. We will assume, however, that adjustment costs are present and will work with two different forms

[7] The difference between a partial expensing allowance and a pure investment subsidy can be easily described in the context of equation (2). Under partial expensing, when the household deducts its allowed proportion of current investment spending from current capital income future depreciation allowances are scaled back accordingly (hence the term $1 - X_t$ multiplying the depreciation allowance terms). By contrast, under an investment subsidy the allowance today would leave future depreciation allowances unaffected, so that allowable deductions to taxable income would be given by $X_t P_t I_t^i - \sum_{v=1}^{\infty} \delta(1-\delta)^{v-1} P_{t-v} I_{t-v}^i$.

[8] Intuitively, reasonable changes to the assumed pattern of capital depreciation have a very small effect on the cost of capital relative to the effect that obtains from the presence or absence of an expensing allowance. Hence, it is this latter factor that is the dominant influence on the contour of the model's impulse response function for investment.

of such costs. The first form assumes that is it costly to adjust firms' *capital* stocks, with adjustment costs taking a quadratic form. This yields the following capital evolution equation:

$$K_{t+1}^{i} = (1-\delta)K_{t}^{i} + I_{t}^{i} \exp\left[\xi_{t}^{i} - \frac{\chi^{k}}{2}\left(\frac{K_{t+1}^{i}}{K_{t}^{i}} - 1\right)^{2}\right], \tag{5}$$

where the parameter χ^k controls the curvature of the capital adjustment-cost function. The second form of adjustment costs assumes that it is costly to adjust *investment* spending such that the capital evolution equation is

$$K_{t+1}^{i} = (1-\delta)K_{t}^{i} + I_{t}^{i} \exp\left[\xi_{t}^{i} - \frac{\chi^{i}}{2}\left(\frac{I_{t}^{i}}{I_{t-1}^{i}} - 1\right)^{2}\right], \tag{6}$$

where the parameter χ^i controls the curvature of the investment adjustment-cost function.

Finally, we bring sticky wages into the model by assuming that households are Calvo wage-setters: In any period, a fraction $(1-\gamma)$ of households can reset their wage, while the remaining fraction γ are constrained to charge their existing wage (which is indexed to the steady-state rate of nominal wage growth).

In the baseline model, then, the household takes as given its initial bond stock A_0^i, the expected path of the gross nominal interest rate R_t, the price level P_t, the rental rate R_t^k, profits income, and the legislated personal income tax rates and expensing allowances (F_t^h, F_t^k, and X_t), and chooses $\{C_t^i, W_t^i, H_t^i, I_t^i, K_{t+1}^i\}_{t=0}^{\infty}$ so as to maximize equation (1) subject to the budget constraint (equation 2), the demand schedule that they face for their labor (discussed below), and the capital evolution process (either equation 5 or equation 6).

2.2 Intermediate- and Final-Goods Producers

The monopolistically competitive firm j chooses each type of differentiated labor $H_t^{i,j}$ and capital K_t^j to minimize its cost of producing output Y_t^j, taking as given the wage rates set by each household $\{W_t\}_{i=0}^{1}$, the rental rate R_t^k, and the production function. Specifically, firm j solves:

$$\min_{\{H_t^{i,j}, K_t^j\}_{t=0}^{\infty}} \int_0^1 W_t H_t^{i,j} di + R_t^k K_t^j$$

$$\text{such that } \left(\left(\int_0^1 H_t^{i,j\,\frac{\psi-1}{\psi}}\,di\right)^{\frac{\psi}{\psi-1}}\right)^{1-\alpha} \left(K_t^j\right)^{\alpha} - FC \geq Y_t^j, \quad (7)$$

where α is the elasticity of output with respect to capital and and FC is a fixed cost (set equal to $FC = \frac{Y_*}{\theta-1}$) that is assumed in order to preclude positive steady-state profits. The cost-minimization problem implies labor- and capital-demand schedules for each firm as well as an expression for the firm's marginal cost MC_t^j. The labor demand functions for each type of differentiated labor are given by $L_t^i = L_t(W_t^i/W_t)^{-\psi}$, where W_t, the aggregate wage, is defined as $W_t = (\int_0^1 (W_t^i)^{1-\psi} dz)^{\frac{1}{1-\psi}}$. We bring sticky prices into the model by assuming that intermediate-goods producers are Calvo price-setters: In any period, a fraction $(1-\eta)$ of firms can reset their price, while the remaining fraction η are constrained to charge their existing price (which is indexed to the steady-state inflation rate).

We also assume a representative final-good producing firm who takes as given the prices $\{P_t^j\}_{j=0}^1$ that are set by each intermediate-good producer, and chooses intermediate inputs $\{Y_t^j\}_{j=0}^1$ to minimize its cost of producing aggregate output Y_t subject to a Dixit-Stiglitz production function:

$$\min_{\{Y_t^j\}_{t=0}^{\infty}} \int_0^1 P_t^j Y_t^j \; dj \text{ s.t. } Y_t \leq \left(\int_0^1 Y_t^{j\,\frac{\theta-1}{\theta}}\, dj\right)^{\frac{\theta}{\theta-1}}. \quad (8)$$

This cost-minimization problem yields demand functions for each intermediate good that are given by $Y_t^j = Y_t(P_t^j/P_t)^{-\theta}$, where P_t, the price of final output, is defined as $P_t = (\int_0^1 (P_t^j)^{1-\theta} dz)^{\frac{1}{1-\theta}}$.

2.3 The Monetary Authority

The central bank sets the nominal interest rate according to a Taylor-style feedback rule. Specifically, the target nominal interest rate $\bar{R}_t$ is assumed to respond to deviations of output and the (gross) inflation rate from their respective target levels $\bar{Y}$ and $\bar{\Pi}$:

$$\bar{R}_t = (\Pi_t/\bar{\Pi})^{\phi_\pi} \left(Y_t/\bar{Y}\right)^{\phi_y} R_*, \quad (9)$$

where R_* denotes the economy's steady-state (equilibrium) interest rate. For simplicity, we will assume that the central bank targets the economy's steady-state level of output, implying that $\bar{Y} = Y_*$. Policymakers smoothly adjust the actual interest rate to its target level:

$$R_t = (R_{t-1})^{\rho} \left(\bar{R}_t\right)^{1-\rho} \exp\left[\xi_t^r\right], \tag{10}$$

where ξ_t^r represents a policy shock.

2.4 The Fiscal Authority

To keep the number of fiscal distortions in the model to a minimum, we assume a role for government that is as simple as possible; namely, one in which the fiscal authority merely raises revenues via taxation and then rebates these revenues as lump-sum transfers T_t^i to households. Hence, the government faces the following budget constraint:

$$\begin{aligned} \int_0^1 T_t^i di \;&=\; Revenue_t = \int_0^1 F_t^h W_t H_t^i di + \int_0^1 F_t^k R_t^k K_t^i di + \int_0^1 F^h Profits_t^i di \\ &+ \int_0^1 F_t^h \left(R_{t-1}-1\right)\left(A_t^i / R_{t-1}\right) di - \int_0^1 F_t^k X_t P_t I_t^i di - \int_0^1 F_t^k Liab_t^{i,\delta} di. \end{aligned} \tag{11}$$

The government's depreciation allowance liability to household i in period t, $Liab_t^{i,\delta}$, is given by:

$$Liab_t^{i,\delta} = \sum_{v=1}^{\infty} \delta\left(1-\delta\right)^{v-1}\left(1-X_{t-v}\right) P_{t-v} I_{t-v}^i = \delta\left(1-X_{t-1}\right) P_{t-1} I_{t-1}^i + \left(1-\delta\right) Liab_{t-1}^{i,\delta}$$

under our assumption that depreciation allowances equal true economic depreciation.[9] Note that if the net stock of bonds in the economy is zero (as it will be when all bonds are domestic and privately issued), then the first term in the second line of equation (11) drops out.

An additional variable that we define here (since it will prove useful when we attempt to score different tax policies) is the present discounted value of revenues. This is given as:

$$PDV_t^{rev} = E_t\left[\sum_{v=0}^{\infty} \frac{\beta^v MU_{t+v}/P_{t+v}}{MU_t/P_t} Rev_{t+v}\right] = Rev_t + E_t\left[\frac{\beta MU_{t+1}/P_{t+v}}{MU_t/P_t} PDV_{t+1}^{rev}\right] \tag{12}$$

where the dependence on the marginal utility of consumption, MU_t, reflects the use of a stochastic discount factor to value future income.

[9] With legislated depreciation rates, this liability equals $\sum_{v=1}^{V} \delta_v^{irs}\left(1-X_{t-v}\right) P_{t-v} I_{t-v}^i$.

Finally, we note in passing that changes in tax policy in our framework can be equated with shocks to suitably specified exogenous processes for the fiscal variables. For example, the introduction of a *permanent* partial expensing allowance is captured by a one-time shock to X_t, where the expensing allowance is assumed to follow an $AR(1)$ process with a unit autoregressive root:

$$X_t = X_{t-1} + \epsilon_t^x. \tag{13}$$

Similarly, a temporary (n-period) partial expensing allowance can be treated as an innovation to X_t under the assumption that the allowance follows an $MA(n-1)$ process:

$$X_t = \epsilon_t^x + \epsilon_{t-1}^x + \cdots + \epsilon_{t-n+1}^x. \tag{14}$$

Naturally, shocks to other fiscal variables (such as F_t^k) can be treated in a parallel fashion.

2.5 The Model's First-Order Conditions

We only consider the first-order conditions that are directly affected by the presence of nominal taxation.

The household's utility-maximization problem yields an intertemporal Euler equation along with a supply schedule for labor:

$$\frac{1}{C_t^\sigma P_t} = \beta E_t \left[\frac{R_t^f}{C_{t+1}^\sigma P_{t+1}} \right], \tag{15}$$

$$\frac{W_t(1-F_t^h)}{P_t} = H_t^s C_t^\sigma, \tag{16}$$

and

$$W_t^i = \frac{\sum_{k=0}^{\infty} \gamma^k E_t \left[((\beta^k MU_{t+k}/P_{t+k})/(MU_t/P_t)) \left(H_{t+k}^i\right)^s \left(C_{t+k}^i\right)^\sigma \psi H_{t+k} \right]}{\sum_{k=0}^{\infty} \eta^k E_t \left[((\beta^k MU_{t+k}/P_{t+k})/(MU_t/P_t)) \left((1-F_t^h)/P_t\right) (\psi - 1) H_{t+k} \right]}. \tag{17}$$

The solution to the household's maximization problem also yields a capital supply condition; however, when adjustment costs are present, this expression is relatively complicated. We therefore instead give here the capital supply equation that obtains when there are no adjustment costs for capital or investment, namely:

$$E_t\left[\frac{R^k_{t+1}(1-F^k_{t+1})}{P_{t+1}}\right] = E_t\left[\frac{R^f_t}{\Pi_{t+1}}\left(1-F^k_t X_t - PDV^\delta_t\,(1-X_t)\right)\right] \\ - E_t\left[(1-\delta)\left(1-F^k_{t+1}X_{t+1} - PDV^\delta_{t+1}\,(1-X_{t+1})\right)\right], \quad (18)$$

where the variable R^f_t is defined by equation (3). The variable PDV^δ_t in equation (18) is the present discounted value of future depreciation allowances that households can deduct from their tax liability; when depreciation allowances for tax purposes are equal to true economic depreciation, this is given by

$$PDV^\delta_t = E_t\left\{\sum_{v=1}^{\infty}\frac{\beta^v MU_{t+v}/P_{t+v}}{MU_t/P_t}\delta\,(1-\delta)^{v-1}\,F^k_{t+v}\right\}, \quad (19)$$

where we again use a stochastic discount factor to value future income streams.[10]

In addition, factor demand schedules (in which labor and capital demand is expressed as a function of output and factor-price ratios) are obtained from the intermediate-goods producers' problem, while the final-goods producer's problem yields demand functions for intermediate goods and an expression for the aggregate price level. Finally, the economy faces the usual market-clearing condition.

2.6 The Log-Linearized Model Equations

We obtain a linear model by log-linearizing the model equations about a deterministic steady state. Again, we mainly focus on describing and interpreting those equations that are directly affected by the presence of a nominal tax system.

The household's Euler equation (15) becomes

$$c_t = E_t c_{t+1} - \frac{1}{\sigma}\left(r^f_t - E_t\pi_{t+1}\right), \quad (20)$$

with π defined as the log-difference of the price level (here and elsewhere, we use lower-case letters to denote log deviations of variables from their steady-state values). As is clearly evident from this equation, consumption growth is a function of the real *posttax* interest rate. The log-linearized posttax *nominal* interest rate is

[10] When allowances are based on legislated depreciation rates, the $\delta(1-\delta)^{v-1}$ term in equation (19) is replaced by δ^{irs}_v.

given by

$$r_t^f = \frac{\frac{\bar{\Pi}}{\beta} - F_*^h}{\frac{\bar{\Pi}}{\beta}} r_t - \frac{\frac{\bar{\Pi}}{\beta} - 1}{\frac{\bar{\Pi}}{\beta}} \cdot \frac{F_*^h}{1 - F_*^h} E_t f_{t+1}^h, \tag{21}$$

where an asterisk in lieu of a time subscript denotes a variable's steady-state value. Finally, the household's labor supply condition log-linearizes to

$$\pi_t^w = \beta E_t \pi_{t+1}^w + \frac{(1-\gamma)(1-\gamma\beta)}{\gamma} \cdot \frac{1}{1+\psi \cdot s} \left[\frac{F_*^h}{1 - F_*^h} \cdot f_t^h + \sigma \cdot c_t + s \cdot h_t - w_t \right], \tag{22}$$

where π_t^w is the log-difference of the nominal wage.

When capital adjustment costs are present, the capital supply condition yields the following log-linear expression for the user cost:

$$\begin{aligned} E_t r_{t+1}^k = & \left[\frac{F_*^k}{1 - F_*^k} \right] f_{t+1}^k + \left[\frac{1}{1 - \beta(1-\delta)} \right] \left(r_t^f - E_t \pi_{t+1} \right) \\ & + \left[\frac{1}{1 - \beta(1-\delta)} \right] (q_t - \beta(1-\delta) E_t q_{t+1}) \\ & - \left[\frac{\chi^k \cdot \delta}{1 - \beta(1-\delta)} \cdot \frac{1}{1 - PDV_*^\delta} \right] (\beta E_t k_{t+2} - (1+\beta) k_{t+1} + k_t), \end{aligned} \tag{23}$$

with

$$\begin{aligned} q_t &= -\xi_t^i - \frac{PDV_*^\delta}{1 - PDV_*^\delta} \cdot pdv_t^\delta - \frac{F_*^k - PDV_*^\delta}{1 - PDV_*^\delta} \cdot X_t \\ pdv_t^\delta &= (\beta/\bar{\Pi})(1-\delta) E_t pdv_{t+1}^\delta + (1 - (\beta/\bar{\Pi})(1-\delta)) E_t f_{t+1}^k - r_t^f. \end{aligned} \tag{24}$$

When investment adjustment costs are present, the capital supply condition yields the following log-linear expression for the user cost:

$$\begin{aligned} E_t r_{t+1}^k = & \left[\frac{F_*^k}{1 - F_*^k} \right] f_{t+1}^k + \left[\frac{1}{1 - \beta(1-\delta)} \right] \left(r_t^f - E_t \pi_{t+1} \right) \\ & + \left[\frac{1}{1 - \beta(1-\delta)} \cdot \frac{1}{1 - PDV_*^\delta} \right] (q_t - \beta(1-\delta) E_t q_{t+1}) \end{aligned} \tag{25}$$

with

$$q_t = -\xi_t^i - PDV_*^\delta \cdot pdv_t^\delta - \left(F_*^k - PDV_*^\delta \right) X_t - \chi^a \cdot E_t \beta i_{t+1} + \chi^a (1+\beta) i_t - \chi^a \cdot i_{t-1}.$$

As can be seen from these equations, there are two important ways in which the presence of a nominal tax system affects aggregate demand determination. First, consumption growth and the user cost are both functions of the real *posttax* interest rate, which will not move one-for-one with changes in the nominal interest rate when income taxes are nonzero. Second, because depreciation allowances are valued at historic cost, they will be worth less in current-dollar terms when inflation is positive—put differently, the nominal nature of depreciation allowances implies that *nominal* interest rates determine their discounted present value. Hence, an increase in nominal interest rates raises the user cost of capital in two ways: first by raising the posttax real interest rate, and second by lowering the expected present value of depreciation allowances.[11]

The other components of the log-linearized model are quite standard. Capital and labor demand are given by

$$k_t = \left(\frac{\theta - 1}{\theta}\right) y_t + (1 - \alpha)\, w_t - (1 - \alpha)\, r_t^k \tag{26}$$

and

$$h_t = \left(\frac{\theta - 1}{\theta}\right) y_t - \alpha\, w_t + \alpha\, r_t^k, \tag{27}$$

respectively, while the log-linearized aggregate supply relation is a new-Keynesian Phillips curve of the form

$$\pi_t = \beta\, E_t \pi_{t+1} + \frac{(1 - \eta)\,(1 - \eta\beta)}{\eta} mc_t. \tag{28}$$

Finally, the log-linearized monetary policy rule is

$$r_t = \rho r_{t-1} + (1 - \rho)\left(\phi_\pi E_t \pi_{t+1} + \phi_y y_t\right) + \xi_t^r, \tag{29}$$

which combines equations (9) and (10).

2.7 Calibration

The structural parameter values that we use in order to calibrate the baseline model are summarized in the table below. The values for α, σ^{-1}, and θ are set so as to match Kimball's (1995) preferred calibration; β is taken from Clarida, Galí, and Gertler (2000, p. 170); and δ is computed from the depreciation rates and nominal

[11] The dependence of the user cost on nominal interest rates provides another motivation for using a model with nominal rigidities to examine the effect of investment tax incentives, as such a model permits nontrivial responses of the inflation rate to a shock.

stocks in Katz and Herman (1997). None of these is particularly controversial.[12] For χ^k, we choose a value that gives our capital adjustment cost function the same curvature properties as Kimball's specification; more concretely, the adjustment costs under this calibration are such that, following a permanent shock (and in *partial* equilibrium), the capital stock adjusts 30 percent of the way to its desired level after one year.[13] For investment adjustment costs, our assumed value of χ^i is set in order to yield a capital stock response in the flexible-price model that is broadly similar to the response that obtains under capital adjustment costs. Finally, our assumed values for η and γ imply that prices and wages are fixed for one year on average, which is again standard; conditional on the value for η, our assumed (inverse) labor supply elasticity s is then chosen so as to yield an elasticity of inflation with respect to output that is similar to what Clarida, *et al.* employ in their work.[14]

For the policy-related parameters, the values for F_*^h and F_*^k that we assume are intended to capture the average marginal tax rates on noncapital and capital income that are implied by the current U.S. tax code; a detailed description of how these values were chosen (together with a discussion of how sensitive our results are to different assumptions about F_*^h and F_*^k) is provided in the Appendix. The $\bar{\Pi}$ value we specify implies an inflation target of zero—which is the assumed steady-state value of inflation in the model—while the parameter values we set in our Taylor rule are $\phi_\pi = 1.80$, $\phi_y = 0.0675$, and $\rho = 0.79$, which are the post-1979 values estimated by Orphanides (2001) using real-time data.

[12]Note that our assumed value of θ implies an equilibrium markup of 10 percent. In addition, the depreciation rate δ and discount factor β are expressed at a quarterly—not annual—rate; for example, our assumed value for depreciation equals 13 percent per year.

[13]Kimball's calibration is particularly relevant for our purposes since it is informed by the results of Cummins, Hassett, and Hubbard's (1994) study, which uses variation in business tax rates (including ITC provisions and depreciation allowances) to identify and estimate structural investment equations.

[14]With this value of s, a 2.75 percent increase in wages is required to raise hours supplied by one percent (all else equal). While this implies a labor supply curve that is steeper than what is commonly employed by RBC modellers, it is quite consistent with the range of values found in the micro-labor literature (see, for example, Abowd and Card, 1989, table 10); it also yields a much more realistic implication for the representative consumer's marginal expenditure share of leisure (*c.f.* the discussion in Kimball, 1995, pp. 1267-69).

Calibrated Values of Common Structural Parameters

Parameter	Description	Value
α	Elasticity of output with respect to capital	0.30
σ^{-1}	Intertemporal elasticity of substitution	0.20
ψ	Elasticity of substitution of labor	11
θ	Elasticity of substitution of intermediates	11
δ	Depreciation rate	0.034
β	Households' discount factor	0.99
χ^k	Curvature param. in capital adj. cost function	170
χ^i	Curvature param. in investment adj. cost function	4.2
$(1-\gamma)$	Probability household can reset wage	0.25
$(1-\eta)$	Probability firm can reset price	0.25
s	Inverse labor supply elasticity	2.75
F_*^h	Steady-state tax rate on noncapital income	0.30
F_*^k	Steady-state tax rate on capital income	0.48
$\bar{\Pi}$	Inflation target	1.00

3 Effects of Partial Expensing Allowances

In this section, we use the baseline model to examine the effects of permanent and temporary changes in the expensing allowance on capital investment, with a particular focus on the way in which the general-equilibrium character of the model influences its response to fiscal shocks.

To provide a useful benchmark, we first present results from a *partial*-equilibrium model that uses the same neoclassical investment specification that underpins the general-equilibrium model. Hence, any difference in results that obtains under the general-equilibrium framework arises because of the effects that changes in investment demand have on output, real interest rates, and consumption demand. In addition, when we compare the results from our general-equilibrium setup to those that obtain in a partial-equilibrium analysis, we use a version of the baseline model in which prices are assumed to be fully flexible (since aggregate price rigidities are irrelevant when output is exogenous). Later, this will permit us to separately identify the role played by sticky prices in our framework.

3.1 Effect of a Permanent Partial Expensing Allowance

We first consider the effects of a permanent 50 percent expensing allowance.[15] Figure 1 shows the predicted responses of the capital stock, gross investment, and the real rental rate from the partial-equilibrium model, while Figure 2 gives the corresponding responses from the flexible-price version of the baseline model. (As consumption is an endogenous variable in the general-equilibrium model, we also plot its response in Figure 2.)[16] Results from the models with capital adjustment costs are plotted in blue, while results from models that assume investment adjustment costs are plotted in red.

In both the partial- and general-equilibrium frameworks, the presence of the expensing allowance makes new capital a more attractive investment. Households therefore immediately begin to purchase capital goods, which raises the economy's capital stock; the aggregate rental rate then falls as this new capital is added to the economy. In addition, as one would expect, the initial responses of investment and the capital stock are smaller under investment adjustment costs. A closer comparison of the two classes of models reveals some important differences, however. In the partial-equilibrium model, the only constraint agents face in adding to the capital stock is the presence of some type of adjustment costs. By contrast, in a general-equilibrium framework, additional capital spending can only occur if more output is produced and/or a greater share of output is devoted to investment. In the model, this process is mediated by higher real interest rates (not shown), which induce households both to give up some of their consumption and to supply more labor (thus raising output).[17]

It is also important to note that essentially all of the sluggishness of the response of the capital stock in the general-equilibrium model reflects the endogenous reaction of the other variables in the model. This can be most clearly seen by comparing the path of the capital-output ratio in the baseline general-equilibrium models to

[15] We choose 50 percent for our example because it corresponds to the size of the (temporary) expensing allowances that were instituted under the 2003 and 2008 fiscal stimulus acts.

[16] All variables are expressed as percentage deviations from their steady-state values, with the exception of the rental rate, which is given as a percentage-point deviation at a quarterly rate.

[17] Note that the rise in real rates actually pushes the economywide real rental rate slightly above its baseline level for several periods after the expensing allowance comes into effect. (Intuitively, the rise in aggregate demand that results from the increased demand for investment goods makes installed capital more valuable.) Even so, there is still an incentive to invest, since the expensing allowance implies that *new* capital remains attractive even with the rise in real rates.

its path in a third version of the model in which adjustment costs are completely absent (Figure 3). As is evident from this plot, capital or investment adjustment costs have a relatively small incremental effect on the path of the capital-output ratio that obtains in the general-equilibrium model. This point can also be illustrated by noting that the capital-output ratio eventually rises about eight percent above its baseline level as a result of the expensing allowance. In the partial-equilibrium model, therefore, the capital stock has moved roughly three-fourths of the way to its long-run value after twenty quarters. In the general-equilibrium setup, however, the capital-output ratio has moved about a third of the way to its long-run level after the same period of time has elapsed.

3.2 Effect of a Temporary Partial Expensing Allowance

We now turn to an examination of the effects of partial expensing allowances that are put into place for a limited period of time. This adds an important forward-looking aspect to the model, since firms' current behavior will anticipate the expected future change in tax policy. As a result, the model's dynamic responses will be richer, and will further highlight how the general-equilibrium nature of the analysis influences the results. The specific experiment we consider is the introduction of a 50 percent expensing allowance that lasts for three years; all agents are assumed to fully understand and believe the temporary nature of the allowance.

Panel A of Figure 4 plots the predicted responses of capital, investment, and the rental rate from the partial-equilibrium model (with capital adjustment costs—the blue lines—or investment adjustment costs—the red lines) following the introduction of the temporary expensing allowance. As before, the new allowances make new capital investment (temporarily) more attractive, thereby leading to a gradual increase in the capital stock and an immediate jump in investment expenditure; over time, as more capital is added to the economy, the aggregate rental rate declines. Interestingly, however, in this case the temporary nature of the allowances induces firms to "pull forward" their investment spending (as can be seen from the figure, the path of the capital stock following a *permanent* increase in the expensing allowance—plotted here as a thin line—lies below the response from the temporary-allowance case for the first four years). Later, when the expensing allowance expires, the capital stock lies above its steady-state level. Disinvestment is costly, however (there are adjustment costs), and so takes place over an extended period. The result is a persistent investment "pothole," as the level of investment falls *below* its steady-state level. Finally, when investment adjustment costs are assumed, the response of investment is smoother and shows a more pronounced hump (with the peak of the hump occurring about a year before the expensing allowance expires); in addition, the decline in investment that occurs immediately after the expiration of the expensing allowance is not as sharp and is spread over a longer period of time. Similarly, the swings in the rental rate are more muted as well.

The responses of these variables (and consumption) in the flexible-price general-equilibrium model are plotted in panel B of Figure 4. As is apparent from a comparison with the partial-equilibrium case, the responses of capital and investment are smaller in the general-equilibrium model (note the differences in scales across the two panels); in addition, there is no longer an investment pothole inasmuch as investment remains above its steady-state level even after the expensing allowance comes off (though we still obtain a sharp drop in the level of investment—and thus a reduction in its growth rate—in the period that the allowance expires). Once again, the source of this more muted response of investment is the endogenous response of real interest rates and consumption to changes in investment demand.[18] In general equilibrium, higher aggregate demand pushes up real interest rates (this is needed in order to call forth more saving), which acts to attenuate the increase in investment and the capital stock. Then, when the expensing allowance comes off, the resulting decline in aggregate demand is partly buffered by a reduction in real rates. Both of these factors imply that the resulting overcapacity (and desire to disinvest) is not as severe.

It is worth noting that very little investment is pulled forward under a temporary allowance in the general-equilibrium case (this can be seen from a comparision of the leftmost plots in panels A and B of the figure). Put differently, the usual conclusion that a temporary investment tax incentive will have a greater (short-term) effect on investment than a permanent tax change—an insight that is readily drawn from the partial-equilibrium framework—need not be correct once general-equilibrium considerations are taken into account.[19]

[18]Note that, under our calibration, the contribution of consumption to output growth (which here is analogous to nonfarm business output) is a little less than four times as great as that for investment.

[19]This is not, of course, a completely general result: As Auerbach (1989) demonstrates, the differential effects on investment of temporary and permanent tax changes (or any change to the

3.3 Expensing Allowances When Prices and Wages are Sticky

Up to this point, we have examined versions of the general-equilibrium model in which prices and wages were assumed to be fully flexible (this was done in order to permit a direct comparison with the partial-equilibrium setup). We now assume that prices and wages are sticky by incorporating the log-linearized aggregate supply relation (equation 28) and labor supply condition (equations 16 and 17) into the model.

Panel C of Figure 4 plots the responses of capital, consumption and investment, and the real rental rate from this model following the introduction of a three-year, 50 percent expensing allowance. Comparison with panel B of the figure reveals that adding nominal rigidities to the general-equilibrium model yields an investment response that is much greater than in the flexible-price case (again, note the difference in scales across the two sets of charts). The intuition for this finding is relatively straightforward. Under sticky prices, firms commit to meeting all demand for their output at their fixed, posted price. Since output is partly demand-determined, there is less need for consumption to be crowded out through an increase in real interest rates, since a positive aggregate demand shock is partly met by increased supply (this is assisted by the presence of sticky wages, which yields a larger increase in labor input). In addition, sticky prices make firms more concerned with their capacity (now and in the future), since an increase in demand will cause a rise in their real marginal costs—and, hence, a decline in their real profits—unless they increase their capital stock. Similarly, there is an incentive to disinvest more rapidly in the face of a slump in demand, since firms are not able to make up for a demand shortfall by cutting prices. Finally, the movements in the rental rate for capital reflect the interaction of these swings in capital demand with currently available capital supply.[20]

cost of capital) depends on the nature of the adjustment-cost function. However, our result obtains for both of the adjustment-cost specifications that we consider under reasonable calibrations. Moreover, there is invariably a pronounced difference between the partial- and general-equilibrium predictions of the model, which is the point that we are seeking to establish.

[20] The presence of nominal rigidities also affect the model's response to a *permanent* change in expensing allowances (not shown). As noted earlier, the fact that depreciation allowances are calculated using historical costs implies that the *nominal* interest rate has an independent influence on the cost of capital (by determining the present value of future depreciation allowances). A permanent expensing allowance yields a permanently higher level of the capital stock, which in turn implies permanently lower marginal costs and persistently lower inflation. As a result, nominal interest rates and the cost of capital both decline, which generates a larger eventual response of

What is much more surprising, however, is that the response of investment in the general-equilibrium model with sticky prices and wages is actually *larger* than the response that obtains in the partial-equilibrium model. This result stands in sharp contrast to the existing literature on tax-based investment incentives, which invariably finds that introducing general-equilibrium elements—specifically, the endogenous response of real interest rates that mediates the clearing of the goods market—significantly attenuates the response of investment and output relative to the partial-equilibrium case. In rough terms, we can think of the results from the partial-equilibrium model as being similar to what would obtain under a horizontal aggregate supply curve, while the flexible-price general-equilibrium model's results are what we might expect from a model with a vertical aggregate supply schedule. Thus, it is not unreasonable to expect that adding sticky prices and/or wages would result in a larger general-equilibrium response than a flexible-price model. But this does not explain why the model with nominal rigidities yields a larger response than the partial-equilibrium model.

To explore this finding further, we consider an additional set of results (summarized in Figures 5 and 6) that compare the responses of the capital stock, investment, and the rental rate under various types of nominal rigidities and under alternative assumptions regarding the type of nominal distortions that are present in the tax system. (The results in Figure 5 are from the model with capital adjustment costs; for completeness, Figure 6 gives results for the model with investment adjustment costs.) We present results for a model with sticky prices *and* sticky wages (the baseline case—panel A), a model with sticky prices only (panel B), and a model with sticky wages only (panel C); these responses (the solid blue or red lines) are plotted against the corresponding response from the partial-equilibrium model (the dashed black line). In each case, we compute the model's responses under the "unindexed" tax system that we have been assuming up to this point (the term "unindexed" is used to highlight the fact that depreciation allowances in this case are computed using the historical cost of investment). We also examine an alternative, "indexed" system in which depreciation allowances are calculated using *current* costs (these responses are given by the dotted blue or red lines); although this system does not reflect the actual way that allowances are computed in the U.S. tax code, it is useful

the capital stock.

in that it permits us to isolate the implications of a nominal tax code.

From these results, it is apparent that the assumption of sticky wages and the presence of an unindexed nominal tax system are responsible for pushing the investment responses of the fully specified general-equilibrium model above the partial-equilibrium model's responses. If we begin by comparing panels B and C, which obtain from a model with sticky prices only (panel B) or sticky wages only (panel C), we see that the investment response is larger for the sticky-wage model. This stems from the well-documented fact that the aggregate supply schedule in a sticky-wage model with a given contract length will be much flatter than the AS curve from a model with sticky prices (and the same contract length).[21] This can also be seen by considering the new-Keynesian Phillips curves that obtain under sticky wages and sticky prices; while the two AS relations take very similar forms, there is an additional term in the wage Phillips curve (the $\frac{1}{1+\psi \cdot s}$ term) that reduces the effect of the driving process on wage inflation. Indeed, if we were to force this term to equal one, the responses from the sticky-wage and sticky-wage/sticky-price models would be very close in magnitude to the model with sticky prices only.[22]

We next assess the effect that an unindexed nominal tax system has on the model's responses. (Again, in Figures 5 and 6 the solid blue or red lines give the results for an unindexed tax system, while the dotted blue or red lines give the results for an indexed tax code.) Comparing the two sets of responses reveals that the presence of an unindexed tax system makes an important contribution to pushing the investment responses from the sticky-wage and sticky-wage/sticky-price models above the responses from the partial-equilibrium model. To determine what feature of the unindexed system is reponsible for amplifying the response of spending to a temporary partial expensing allowance, we plot the responses of a number of additional variables from the stocky-wage/sticky price model in Figure 7 (for the version of the model with capital adjustment costs) and Figure 8 (for the version with investment adjustment costs).

Consider the response of investment after the expensing allowance is removed. In

[21]See Huang and Liu (2000).

[22]A corollary to this point is that it is possible to magnify the responses of the sticky-price model by increasing the expected duration of a contract. In particular, raising the expected length of time that a price is fixed from one to three years pushes the response of the sticky-price model above that of the partial-equilibrium model (though it remains below the sticky-wage and sticky-wage/sticky-price models' responses).

the models with an indexed tax system, investment is only slightly above its steady-state level once the allowance has come off; with an unindexed system, investment over this period is considerably higher. In the indexed model, investment is boosted after the allowance has come off by a lower real interest rate. This in turn arises because of monetary policy: Inflation is below its steady-state level, which allows the central bank to ease (despite output's being above its steady state as well). In an unindexed model, however, investment is also a function of *nominal* interest rates (recall that the present value of depreciation allowances—which enters the user cost expression—depends on nominal interest rates, since depreciation allowances are computed using historical investment prices under an unindexed tax code). Hence, the lower inflation rate further stimulates investment by inducing lower nominal interest rates. In addition, the investment responses are reinforced in the following way: If the capital stock remains elevated above its steady-state level, then the rental rate of capital will be held down, thereby driving inflation lower. This then lowers nominal interest rates, which further stimulates investment and props up the capital stock.

What about the period before the expensing allowance comes off? Here, the investment response is boosted because the level of the capital stock is higher than it otherwise would be once the allowances expire. The presence of adjustment costs damps the response of the capital stock and investment; in particular, because investors will want to reduce their holdings of capital after the allowances expire—and because making changes to the capital stock or investment plan is costly—they do not permit investment to increase by as much as it otherwise would. But if investors know that the capital stock will remain higher after the allowances come off (as it will under a nominal tax system), then they are willing to add to the capital stock more aggressively when the allowances are in place.

The results in this subsection, then, leave us with two important lessons. First, the nominal nature of the tax system (specifically, the use of hostorical costs in calculating depreciation charges against current income) has an important influence on the response of investment to a temporary partial expensing allowance. Indeed, in a fully specified model with a nominal tax system, it is even possible for the responses in a general-equilibrium framework to exceed those found in a partial-equilibrium setup. Second, and more tentatively, it is not necessarily the case that expansionary fiscal policy will be inflationary: Under the calibration we assume, inflation can actually be pushed below its steady-state level for a prolonged period of time despite levels of investment, consumption, and output that also exceed their steady-state values.

3.4 Robustness Checks

A number of features of our model can conceivably affect the predicted response of investment to a change in tax policy. For example, the responses of saving and hours worked to changes in the real interest rate will obviously influence the response of investment spending to a tax shock; similarly, the independent role of the *nominal* interest rate on capital demand (which arises as a result of the nominal character of depreciation allowances) yields an additional way in which our characterization of the model economy's aggregate supply relation affect the model's predicted responses. Finally, a less obvious aspect of the model's specification that turns out to have an interesting effect on our results is our implicit assumption that labor and capital can be used to produce either consumption or investment goods (which in turn reflects the single-good nature of our baseline theoretical framework). We therefore briefly consider how our results are affected by employing alternative specifications for household consumption and aggregate supply, and also extend the model to incorporate sector-specific factor inputs. With one exception, each extension builds on the baseline version of the sticky-price model with investment adjustment costs.[23]

Modelling habit persistence in consumption: We added "external" habit persistence to our model by making household i's utility depend on $C_t^i - bC_{t-1}$ (where C_{t-1} denotes aggregate consumption).[24] We set b equal to 0.8, which implies a relatively large degree of habit persistence. This extension has almost no effect on the response of investment relative to the baseline model: While habit persistence results in an aggregate log-linearized labor supply curve that now contains an additional term in Δc_t, the smoothness of consumption in the baseline mosel is sufficiently high that Δc_t makes a negligible contribution.

[23] A fuller description of these results is provided in our 2005 working paper.

[24] This particular specification of habit formation is taken from Christiano, Eichenbaum, and Evans (2001).

More inertial price setting: We assume a "hybrid" new-Keynesian pricing equation (due to due to Christiano, Eichenbaum, and Evans, 2001) in which inflation is partially indexed to its own lag. In broad terms, the predicted response for investment is quite similar to the baseline specification: Although the hybrid inflation equation does in fact yield a smaller *initial* response of inflation, after a few quarters the path of the inflation rate is similar to what is obtained in the baseline model (in addition, because we assume that the monetary authority tries to smooth its policy rate, the path of nominal interest rates is also quite similar across the two models). However, because the hybrid Phillips curve imparts more inertia to price setting, the path of inflation (and nominal interest rates) remains higher over a longer period in the alternative model. As a result, the response of investment is attenuated slightly relative to the baseline case.[25]

Putty-clay capital adjustment: Assume a specification in which it is costly to adjust the capital-labor ratio as well as the capital stock (this can be thought of as a convex approximation to a putty-clay investment technology).[26] This additional source of inflexibility implies that there is now less benefit from adjusting the capital stock independently; as a result, the investment response in this version of the model is more muted than what obtains for the model with capital-adjustment costs only (in particular, investment now reaches its peak a little earlier, and also remains higher after the expensing allowance comes off). That said, we do see a much larger swing in the rental rate for capital: Previously, firms facing changes in demand for their output were able to change their production by altering the amount of labor they hired; here this avenue is partly closed off, as it is now also costly to adjust labor inputs. The result is a more pronounced swing in demand for installed capital, which shows up as a relatively larger change in the rental rate.[27]

Multisector production with limited factor mobility: Our baseline model assumes a one-sector production structure in which labor and (existing) capital can be instantaneously and costlessly allocated to the production of either consumption

[25] Recall that nominal interest rates have an independent influence on investment through their effect on the present discounted value of depreciation allowances.

[26] We assume an adjustment cost on the factor mix that is sufficient to roughly halve the swing in the capital-labor ratio that occurs around the expiration date of the temporary expensing allowance.

[27] The responses of pre- and posttax nominal interest rates (not shown) are considerably smoother than the response of the rental rate, which reflects swings in the marginal product of installed capital and the markup of prices over marginal costs.

or capital goods. As a result, a large portion of any increase in investment demand in our baseline model is accommodated by an increase in output, as households supply more hours to the economy's single production sector. A more realistic production structure would involve separate sectors for the production of consumption and investment goods and would take into account the fact that capital and labor inputs tend to be sector specific (particularly over short horizons). In such an economy, it will be more difficult to rapidly increase production in a given sector; in particular, we would expect the rise in investment demand that results from the introduction of a temporary expensing allowance to be only partially met. As a result, we will tend to see a slower response of aggregate investment to a change in tax policy.

We model sector-specific labor inputs by assuming that households incur a (convex) adjustment cost whenever they change the number of hours that they supply to the consumption or investment sector. We then allow for sector-specific capital by assuming distinct accumulation processes for the capital stocks employed in the consumption- and investment-goods sectors. We find that the presence of sector-specific factor supplies yields an investment response to a temporary expensing allowance that is roughly three-fourths as large as the baseline model, but does not change the qualitative features of the response.

4 Is Countercyclical Fiscal Policy Destabilizing?

We now turn to two policy-related questions that can be sensibly addressed in our model. The first concerns whether releated use of temporary partial expensing allowances to smooth cyclical fluctuations in the economy can actually be destabilizing. As Christiano (1984) has argued, this comes about because agents begin to expect that a partial expensing allowance will be enacted when the economy is hit by a sufficiently large shock. They therefore postpone their capital spending in anticipation of the policy, thereby further weakening investment (and the economy) in the runup to the enactment of the expensing allowance. This has arguably become a more realistic concern in the current policy environment, since the last two recessions have seen the passage of significant fiscal stimulus packages that have each included provisions for temporary partial expensing of investment.

The presence of fiscal policy lags suggests that agents would expect any allowance to come into effect in some future period following an adverse shock to the economy. We therefore first consider the effect of an anticipated change in policy; to be concrete, we will look at a temporary partial expensing allowance that is expected to come into effect in a year, and that is then expected to be in effect for 12 quarters.[28] Figure 9 gives the implied response of investment in this case, with results shown for the sticky-price and sticky-price/sticky-wage models, with either capital or investment adjustment costs. In all but one case (the sticky-wage/sticky-price model with investment adjustment costs), the level of investment spending drops when agents first learn that a partial expensing allowance will be put into place in the future. Just as there is a "pull-forward effect" when a temporary expensing allowance is in place (recall section 3.2), when an expensing allowance is expected in the future there is a "postponement effect" that results in a reduction in current investment. This desire to postpone spending is partly offset, however, by a competing desire to avoid large swings in the capital stock or investment spending (depending on the nature of the adjustment costs faced by investors). Hence, the initial dropoff in investment is smaller for models that predict a larger response of the capital stock or investment over the period that the temporary expensing allowance is in place (indeed, it is nonexistent for the sticky-wage/sticky-price model with investment adjustment costs).

With this in hand, we can now look at what happens if a temporary partial expensing allowance is systematically triggered by a deterioration in macroeconomic conditions. The particular shock that we consider is an adverse shock to "investment efficiency," which is the variable ξ_t^i in the various capital evolution expressions we assume (equations 4 through 6).[29] While any negative (non-policy) shock would do for our purposes, it seems plausible that the use of temporary partial expensing allowances as a policy instrument would most naturally arise in an economy where adverse shocks to investment are a common cause of economic downturns.

The dotted lines in Figure 10 give the predicted response of investment spending to a negative investment efficiency shock for our sticky-price and sticky-price/sticky-wage models (once again, blue lines are used for the results from the models with capital adjustment costs, while the red lines are used for the results from the models with investment adjustment costs); for reference, Figure 11 gives the corresponding responses of total output (the contour of these repsonses is basically driven by the

[28] Formally, this is modelled by assuming a suitable pattern of anticipated shocks in equation (14).

[29] A negative shock to ξ_t^i makes agents less willing to purchase capital goods, all else equal.

path of investment spending). The size of the shock is set so that the average decline in investment spending over the first four quarters following the shock across the four models is 17 percent; this is the average decline in real equipment investment (relative to trend) that was seen over the four quarters that followed the start of the 2001 recession. As can be seen from the figures, the magnitude of the initial response to the shock across the various models is determined by the types of nominal rigidities that are present, while the contour is influenced by whether capital or investment adjustment costs are present.

How could we calibrate the likely policy response to such a shock? In the 2001 recession, a 50 percent partial expensing allowance went into effect (over two stages); this was also the size of the allowance that was included in the 2008 stimulus bill. We therefore model the expensing allowances with a process like equation (14), where the size of the "innovation" to the expensing rate is suitably related to the size of the shock to investment (that is, the process is specified so that the shock to investment results in a 50 percent expensing allowance being enacted after one year).

The solid lines in Figure 10 give the response of investment to an adverse investment efficiency shock when a temporary partial expensing allowance is anticipated by agents (again, the corresponding output responses are shown in Figure 11).[30] When capital adjustment costs are present, the anticipated use of partial expensing as a countercyclical stabilization tool actually leads to an initial *reduction* in the levels of investment and output relative to what they would be absent such a policy (the solid lines lie below the dotted lines). This result is sensitive, however, to the specific type of adjustment costs that is assumed: With investment adjustment costs, spending is initially depressed very little (in the model with sticky prices) or not at all (in the sticky-wage/sticky-price model). Hence, the point made in Christiano (1984) receives partial support in our framework, though it is apparently not true under all circumstances.

[30]Note that the investment responses are the sum of the response shown as the dotted line in Figure 10 and the response shown in Figure 9.

5 Partial Expensing *versus* Capital Income Tax Cuts

An alternative policy that is often suggested as a means of stimulating investment spending involves reducing the tax rate on capital income. We next examine the effect of this policy on investment and output, and compare it with the effect of an expensing allowance that has the same impact on government revenues.

Model responses: Figure 12 plots the usual set of model responses (under our two adjustment-cost specifications) following a three-year, 30 percentage point reduction in the capital tax rate F^k. Qualitatively, a temporary cut in the capital tax rate yields a path for investment spending that is much more front-loaded than the path that obtains under an expensing allowance (this is most obvious for the model with capital adjustment costs, though it can also be seen for the model with investment adjustment costs by noting that the peak investment response occurs a little earlier under a capital tax cut). The reason is that the benefits from a reduction in capital taxes are received for as long as the policy is in place; as a result, purchasing and holding a unit of capital for the full three-year period yields the greatest gains. By contrast, an expensing allowance represents a one-time boon (in the quarter that the capital is purchased) that is worth roughly as much at the start of the three-year period as toward the end.

Revenue Impact of Alternative Tax Policies: One of the most useful features of our model is its ability to assess the revenue consequences of alternative tax policies—in particular, we can compare the investment responses induced by a capital tax cut and an expensing allowance, where each policy is constrained to have an identical impact on government revenue.

In Figures 13 through 16 we compare the effect of a temporary capital tax cut with that of a temporary expensing allowance, where each policy is set so as to yield the same change in the present value of government revenues. The present value is computed over a five-year (or 20-quarter) period—this corresponds to the width of the "budget window" that is typically used to score the revenue effects of Federal fiscal policy changes in the U.S.—using the following expression,

$$pdv^{rev}(5)_t = \left(\frac{1-\beta}{1-\beta^{20}}\right) E_t \left[rev_t - \sum_{v=1}^{19} \beta^v \left(rev_{t+v} - \sum_{j=0}^{v-1} (r^f_{t+j} - \pi_{t+1+j}) \right) \right], \quad (30)$$

which corresponds to a log-linearized, finite-period version of equation (12). Figures 13 and 14 give the responses for the model with capital adjustment costs and sticky prices (Figure 13) and sticky prices and wages (Figure 14), while Figures 15 and 16 do the same for the model with investment adjustment costs.

As can be seen from the figures, the expensing allowance typically yields a higher response of investment and output (an exception is the sticky-price model with capital adjustment costs, in which the initial response of investment is slightly smaller under partial expensing). Intuitively, since a capital tax applies to the income from *all* capital while an expensing allowance applies to expenditures on new capital only, the former represents a relatively expensive way to call forth additional investment spending.[31]

6 Conclusions and Directions for Future Work

This paper has attempted to analyze tax-based investment incentives in the context of a fully specified general-equilibrium model. Our analysis revealed three noteworthy results.

- First, our findings highlight the need to pay explicit attention to nominal rigidities. Because the presence of a nominal tax system implies that investment spending and aggregate demand will depend on nominal interest rates, the predicted evolution of inflation will have a significant effect on the predicted response of investment and output. Indeed, for one of the models we considered, the presence of nominal rigidities generated results that contradict the conventional view that the general-equilibrium effects of an tax-based investment incentive are invariably smaller than the policy's partial-equilibrium effects.

- Second, our results provide partial confirmation of the idea that systematic reliance on temporary investment incentives as an instrument of countercyclical stabilization policy can actually be destabilizing.

[31] Note also that the capital stock is invariably much higher at the end of the three-year period under the expensing allowance. Thus, if the revenue consequences of each policy were considered over a longer (or infinite) period, expensing allowances would appear even more attractive.

- Finally, our analysis gives additional support for the result—previously only considered in a partial-equilibrium setup—that, for policies with given revenue effects, a change in the rate of capital taxation typically represents a relatively less efficacious way of stimulating investment than does a change in the expensing rate for newly purchased capital.

A natural next step is to refine the framework developed here into one that can be used for *quantitative* simulations. Attaining this goal would require advancing our analysis along at least three fronts. First, any serious quantitative assessment of expensing allowances must recognize the fact that these tax provisions pertain to equipment investment only. Constructing a fully specified model in which different types of capital are used in production would require making difficult decisions about the degree of substitutability across capital types. However, for the purposes of short-term analysis, it might be sufficient to consider a model in which the stock of structures is assumed to be fixed; this would permit the model to generate more realistic predicted responses of output to tax-induced changes in (equipment) capital without requiring us to explicitly model the investment decision for structures.

Extending the baseline model to an open-economy setting would also represent an important refinement. With no external sector, the endogenous response of the real interest rate is larger following a tax-induced change in investment, since only domestically produced output can be used to meet the additional demand for physical capital. For the U.S. economy, this might be a reasonable first approximation (though see Auerbach, 1989, for a contrary view), as only about a third of the equipment purchased for investment in the U.S. is produced abroad. Nevertheless, an explicit treatment of external considerations in this context—while difficult given the current state of open-economy dynamic general-equilibrium modelling—would yield a framework with even greater practical relevance.

More fundamentally, any model that purports to inform real-world decision-making should be able to demonstrate a reasonable degree of empirical validity. For the application considered here, formal empirical justification is likely to be made more difficult by the fact that the effect of tax changes on investment—let alone on interest rates, consumption, and inflation—is probably very hard to parse out; moreover, relatively few historical examples of these sorts of tax changes exist. This suggests that considering tax changes alone will not allow us to identify all of the model's parameters (though it might be possible to estimate these parameters by examining the model's predicted response to other shocks). In addition, recent U.S. experience with partial expensing allowances suggests that numerous complicating factors (for example, whether state and local governments follow the federal government in enacting parallel provisions in their own tax codes, or whether firms have taxable income to offset when the expensing allowances are in effect) will influence the real-world impact of these policies.

Finally, an additional useful extension would involve constructing an apparatus that would permit the assessment of uncertain future policies. In practice, the likelihood and/or length of proposed tax policies are typically not known with certainty, and this should act to attenuate the economy's response to announced changes in tax policy. Whether the effects of such uncertainty could be quantified in a linear framework, however, is far from clear.

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A Calibrating the Steady-State Tax Rates

This Appendix describes how the effective tax rates on income are calibrated, and discusses how our main results are affected by different assumed values for the capital tax rate.

A.1 Calibration of F_*^h

We follow Edge and Rudd (2002) in using tabulations from the *Statistics of Income* (Table 3.4) to compute average marginal Federal tax rates on earned income. For 2001 (the most recent year for which these data are available), we obtain an average marginal rate that is a little more than 25 percent. We then adjust this figure to reflect income taxation by state and local governments; specifically, data from the National Income and Product Accounts (NIPAs) indicate that state and local personal income taxes represented about 2-1/2 percent of overall personal income in 2001. As this is an average (not marginal) rate, we double it to capture the progressive nature of most state and local tax systems. The sum of these two rates yields the 30 percent average marginal tax rate that we assume.

A.2 Calibration of F_*^k

We require an estimate of the average marginal tax rate on capital income. Excluding depreciation, net capital income can be divided into three categories: dividends, retained earnings, and interest payments. If the corporate income tax rate is given by F_*^c, and if dividends (and capital gains) are taxed at the rate F_*^d, then the effective tax rate on capital income F_*^k is implicitly defined by

$$1 - F_*^k = (1-\omega)(1-F_*^d)(1-F_*^c) + \omega(1-F_*^h), \tag{31}$$

where ω denotes the share of net interest payments in overall capital income. Under current law, the Federal corporate income tax rate is 35 percent, while the Federal tax rate on dividends and capital gains is 15 percent. (We add an additional 5 percentage points to these rates to reflect taxation at the state and local level.) Using NIPA data, we estimate that 17.5 percent of the capital income share is paid out as net interest. All together, these figures imply a capital tax rate of 48 percent, which is the value we assume for F_*^k in our baseline model.

The preceding assumes that the double taxation of dividends (at the corporate and personal level) matters in determining the cost of capital. Under the so-called "new view" of dividend taxation, however, the taxation of dividend income at the personal level is immaterial as far as the cost of capital is concerned.[32] In this case, the first tax term in parentheses on the right-hand side of equation (31) equals one, implying that the effective tax rate on capital income is 38 percent.

Finally, the simplest possible case arises when firms are financed exclusively through debt (in which case taxable corporate income is zero). This implies that all capital income is taxed at the personal tax rate, or that $F_*^k = F_*^h = 30$ percent.

To assess how sensitive our results are to alternative assumptions about F_*^k, the table below gives the long-run change in the real rental rate of capital (expressed as a percent deviation from its steady-state level) following a permanent 30 percent expensing allowance for various assumed values of F_*^k.[33] Based on the figures in the table (and given the log-linear structure of the model), assuming a value of F_*^k consistent with dividend taxation's having no effect on the cost of capital would reduce the model's responses by about a third, while assuming that firms are purely debt-financed would scale them down by about a half.

Long-Run Percent Change in Real Rental Rate

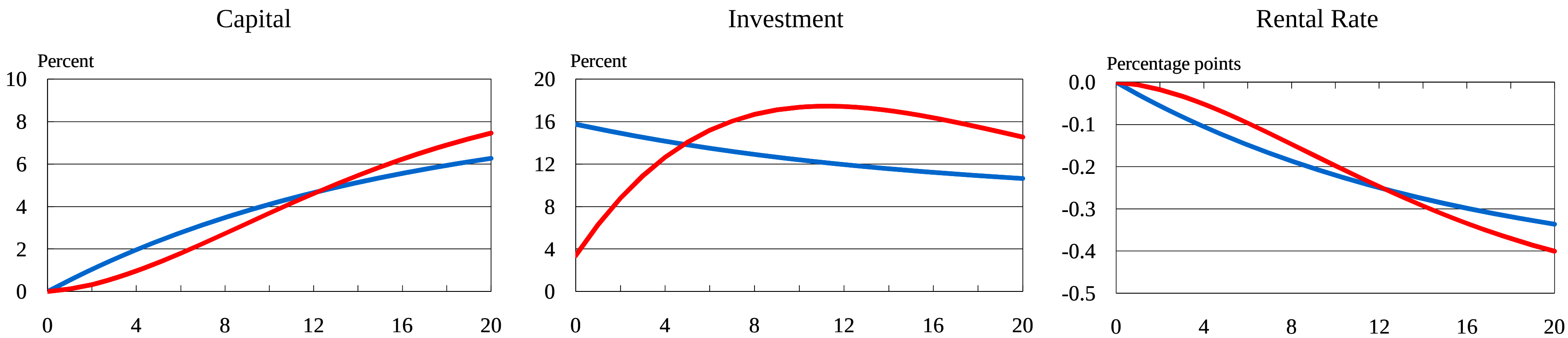
Tax rate F_*^k	Description	Change
48 percent	Baseline assumption	−5.21
38 percent	"New view" of dividend taxation	−3.68
30 percent	Fully debt-financed firms	−2.67

[32] See Auerbach (1979) and Bradford (1981) for discussions of this issue.

[33] The figures in the table give the *direct* effect on the rental rate that obtains from a change in the expensing allowance under the specified tax rate; they do not incorporate any general-equilibrium effects.

FIGURE 1.: Permanent Partial Expensing Allowance in a Partial-Equilibrium Model with Capital (blue) or Investment (red) Adjustment Costs

A.: 20 Quarters



B.: 200 Quarters

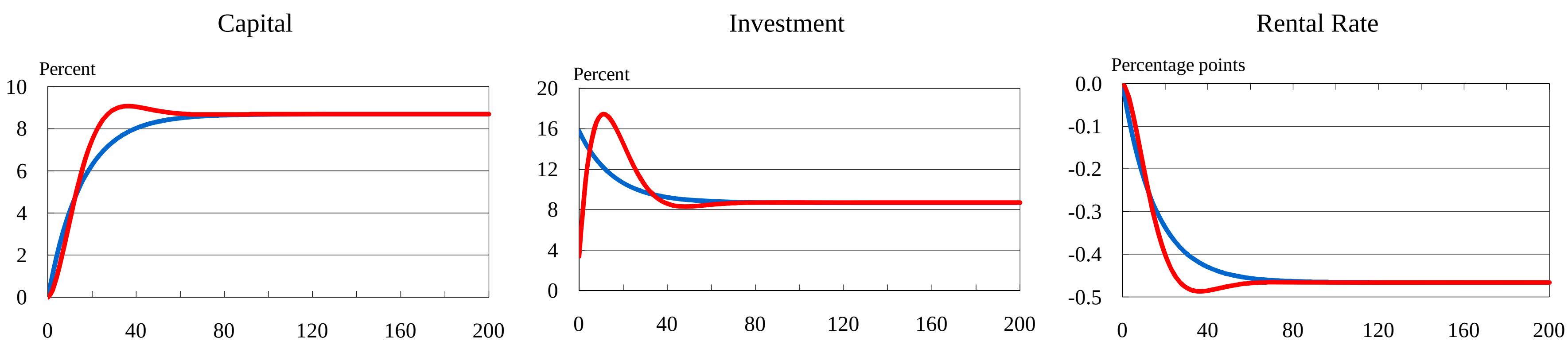
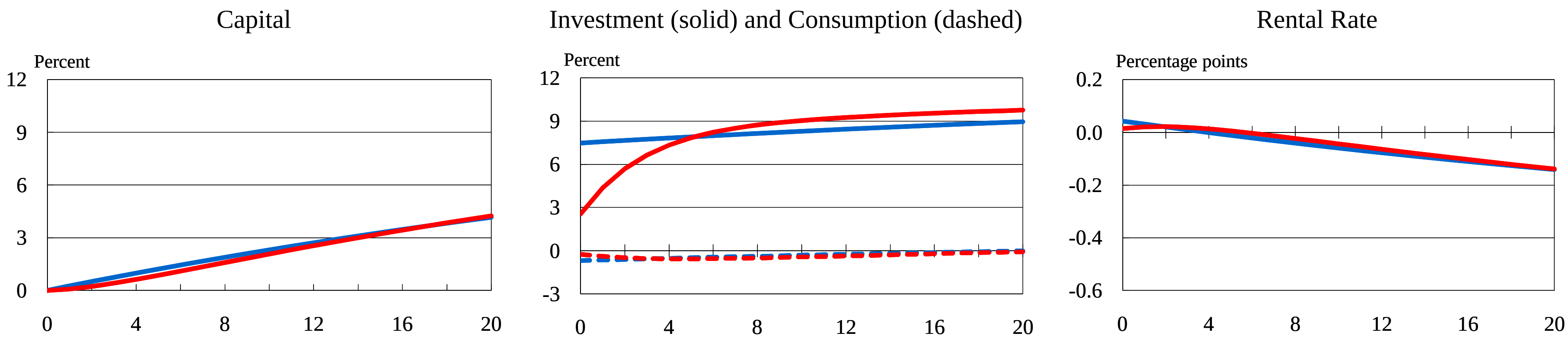


FIGURE 2.: Permanent Partial Expensing Allowance in General-Equilibrium Flexible-Price and Flexible-Wage Models with Capital (blue) or Investment (red) Adjustment Costs

A.: 20 Quarters



B.: 200 Quarters

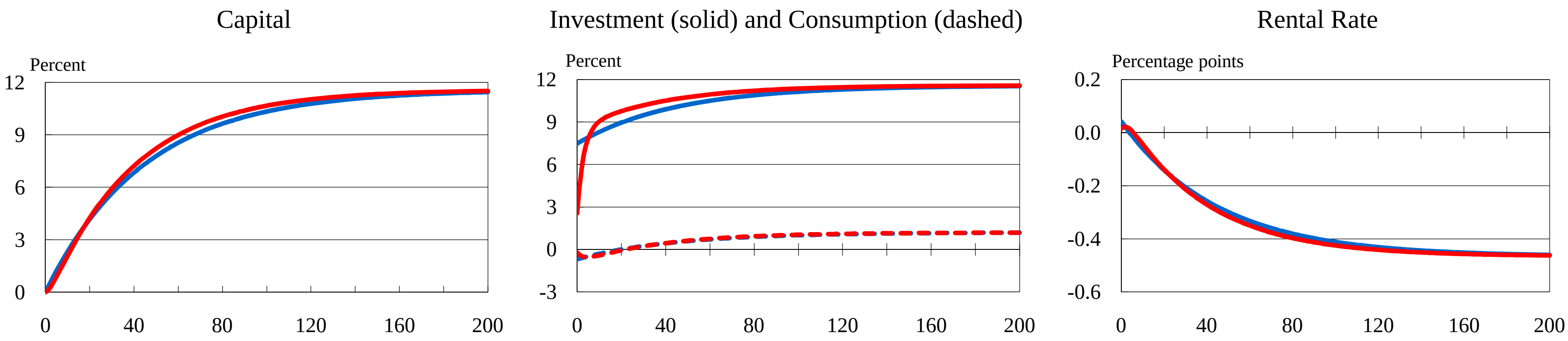


FIGURE 3.: Effect of Permanent Partial Expensing Allowance on the Capital-Output Ratio in General-Equilibrium Flexible-Price and Flexible-Wage Models

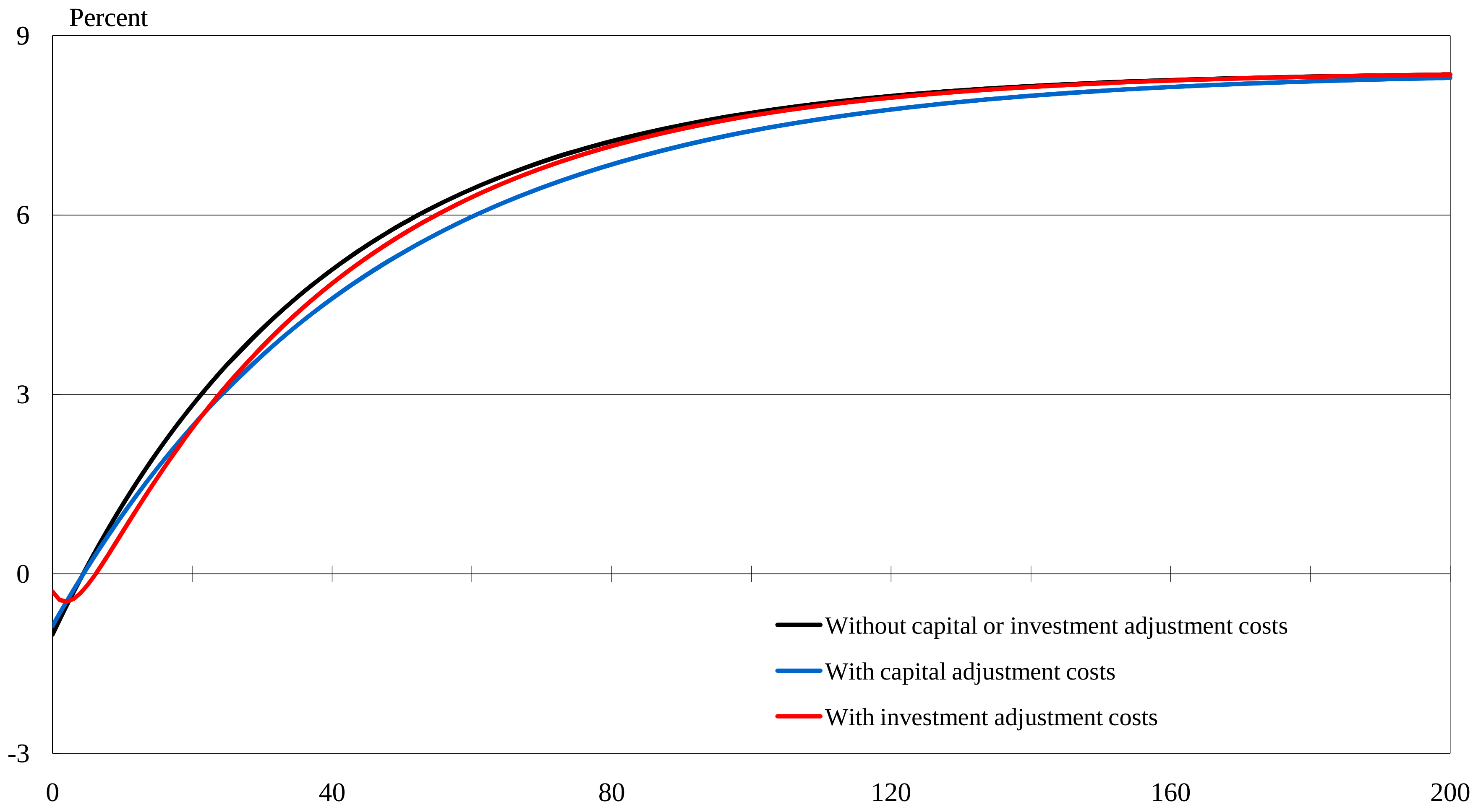
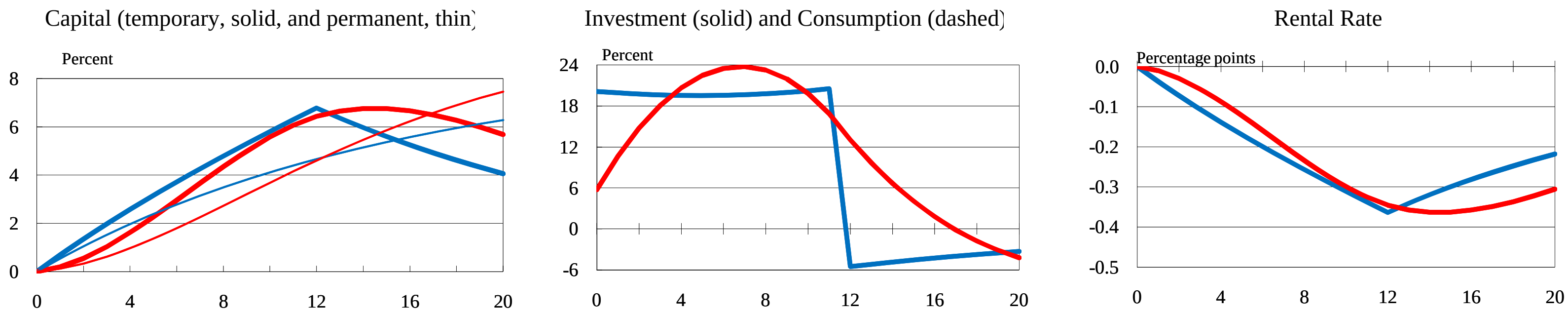
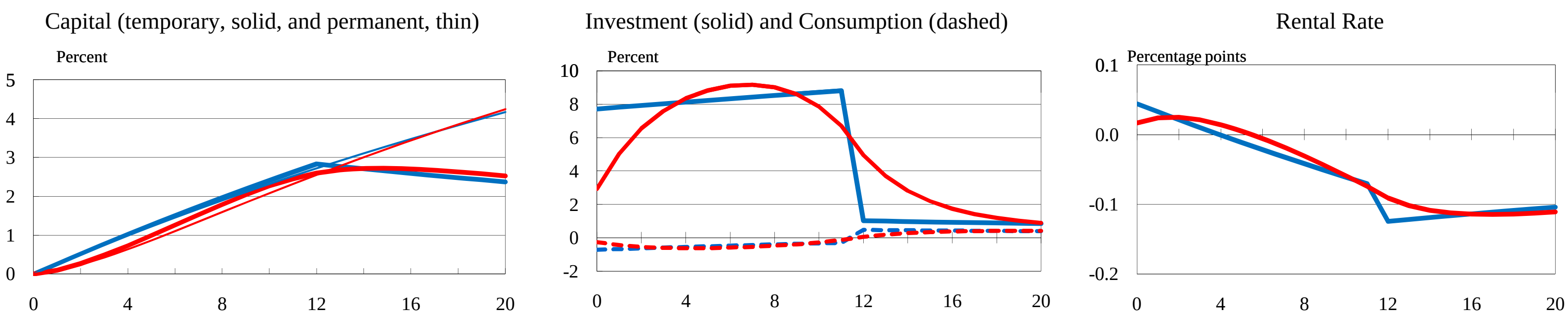


FIGURE 4.: Temporary Partial Expensing Allowance with Capital (blue) or Investment (red) Adjustment Costs

A.: Partial-Equilibrium Model



B.: General-Equilibrium Flexible-Price and Flexible-Wage Model



C.: General-Equilibrium Sticky-price and Sticky-wage Model

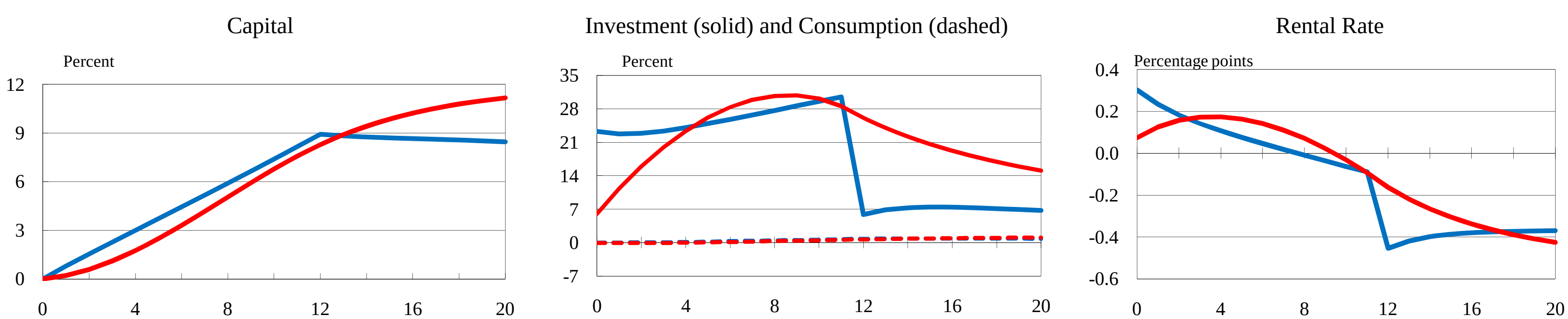
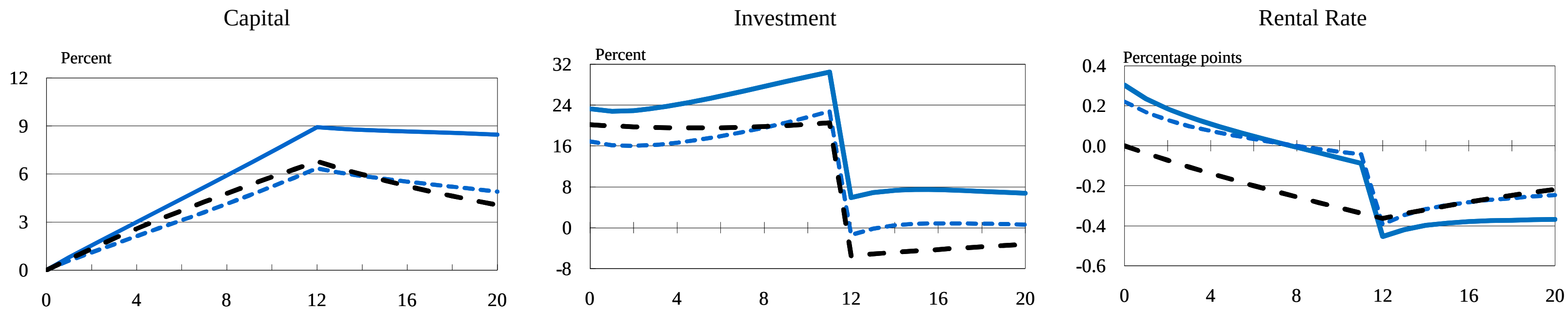
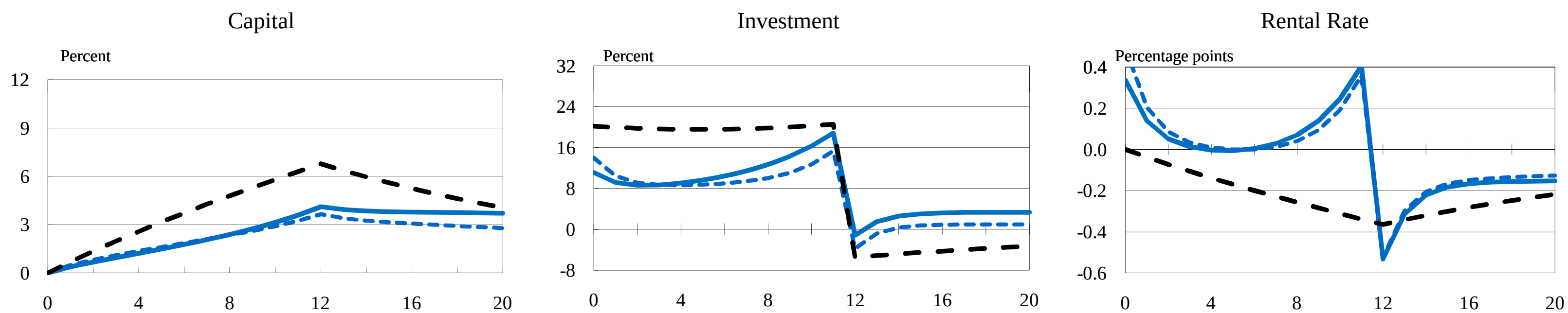


FIGURE 5.: Temporary Partial Expensing Allowance with Capital Adjustment Costs in an Unindexed (solid) and Indexed (dotted) Tax System

A.: Model with Sticky-prices and Sticky-wages



B.: Model with Sticky-prices Only



C.: Model with Sticky-wages Only

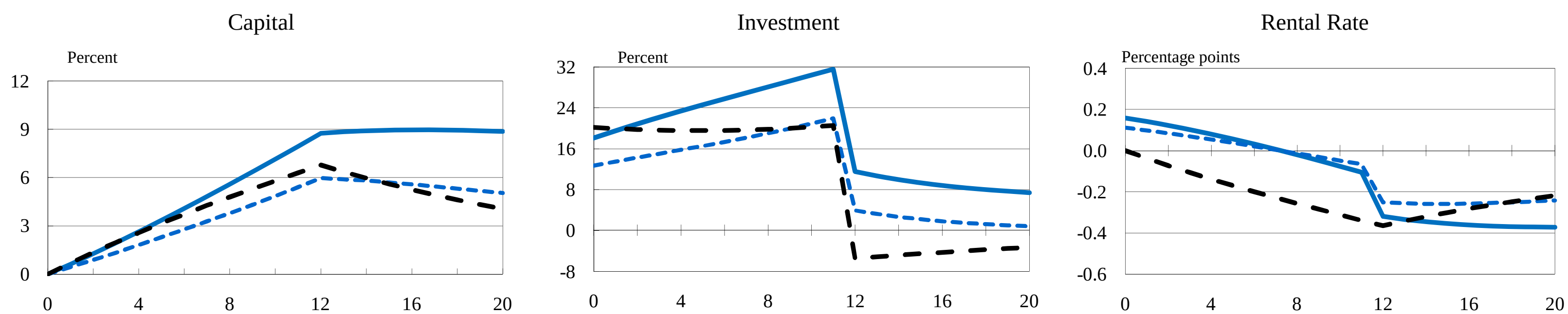


FIGURE 6.: Temporary Partial Expensing Allowance with Investment Adjustment Costs in an Unindexed (solid) and Indexed (dotted) Tax System

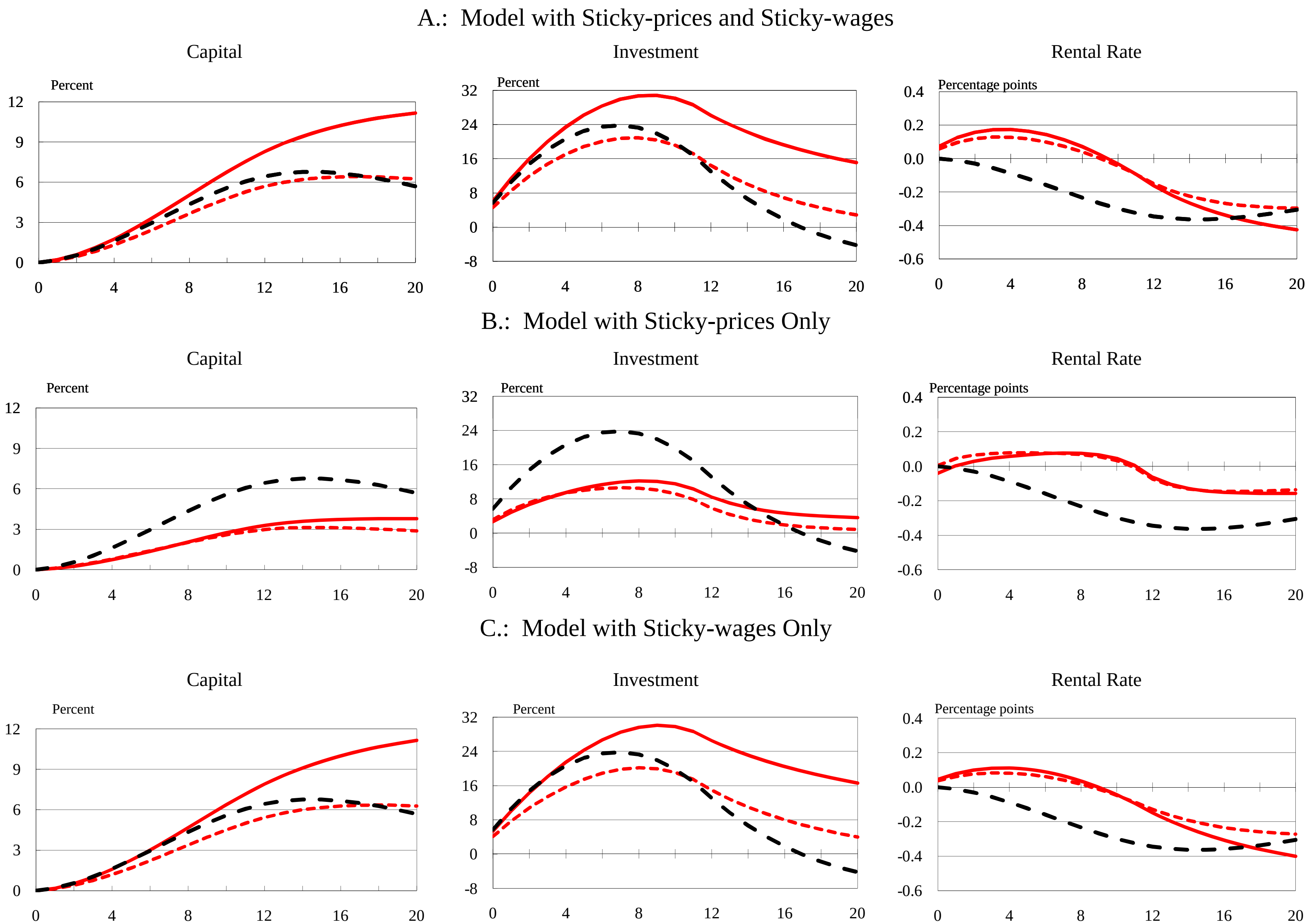


FIGURE 7.: Temporary Partial Expensing Allowance in Sticky-price and Sticky-wage Model with an Unindexed (blue solid), and Indexed (blue dotted) Tax System, and Partial Equilibrium (black dashed) with Capital Adjustment Costs

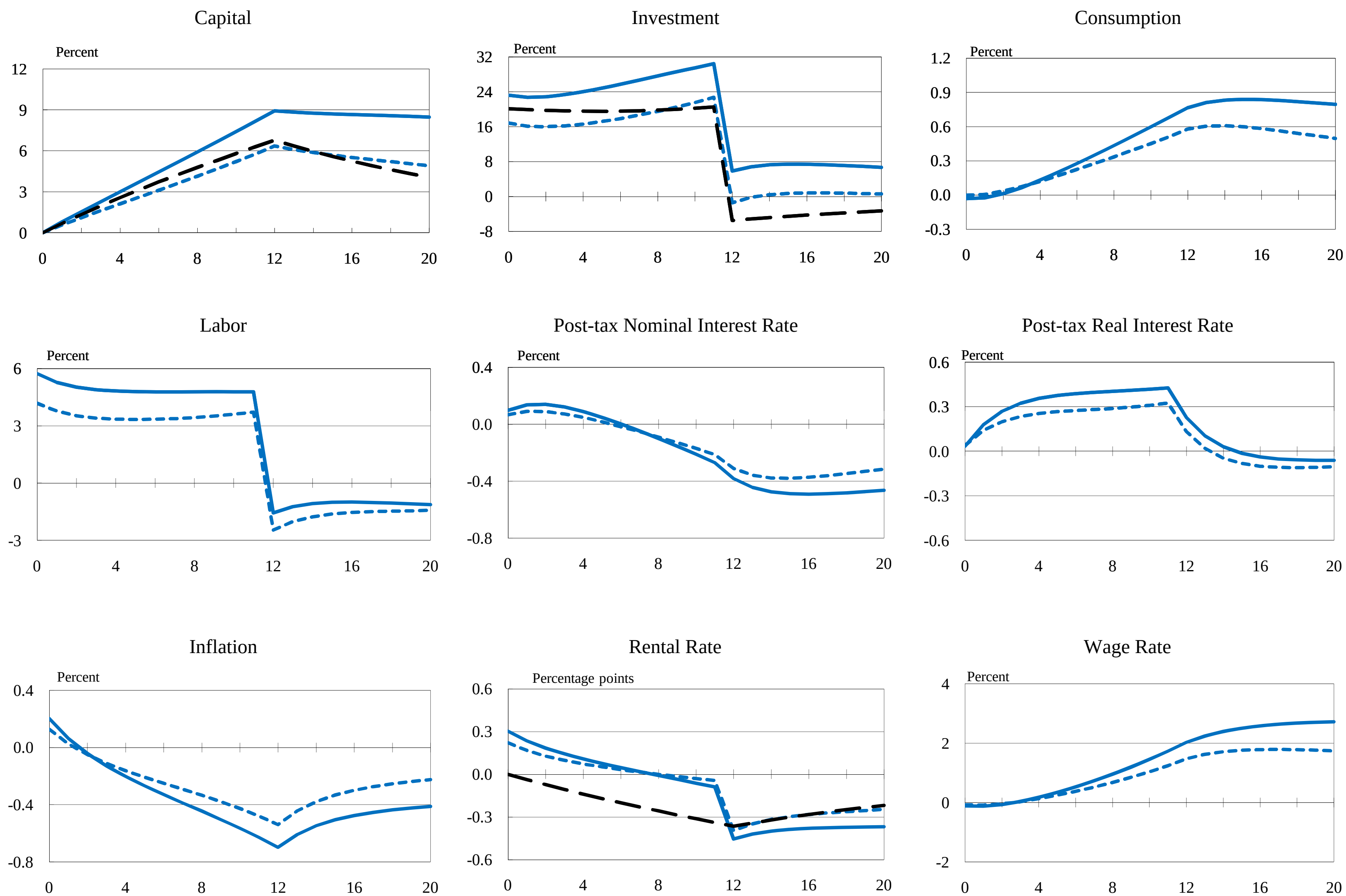


FIGURE 8.: Temporary Partial Expensing Allowance in Sticky-price and Sticky-wage Model with an Unindexed (red solid), and Indexed (red dotted) Tax System, and Partial Equilibrium (black dashed) with Investment Adjustment Costs

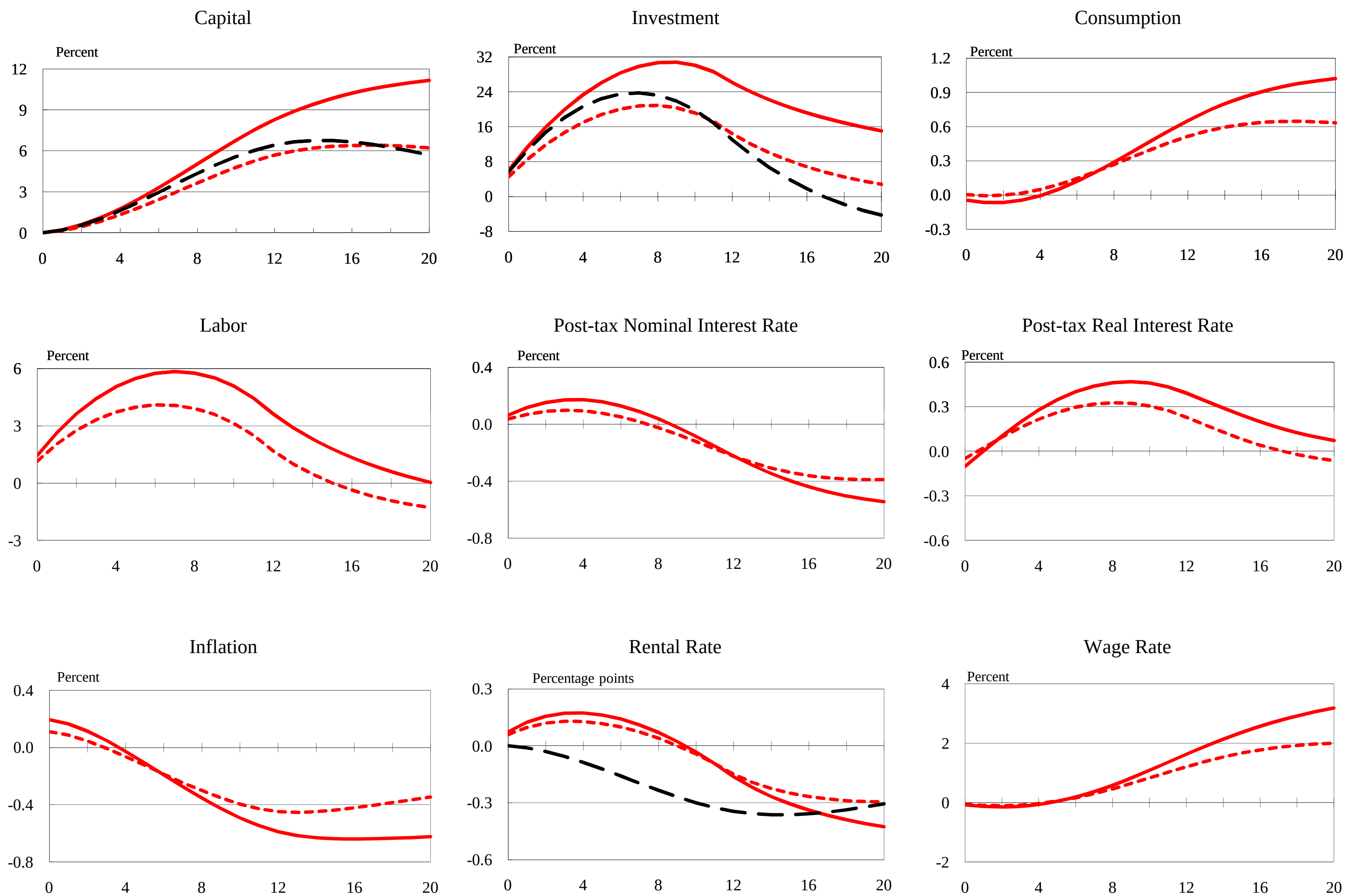
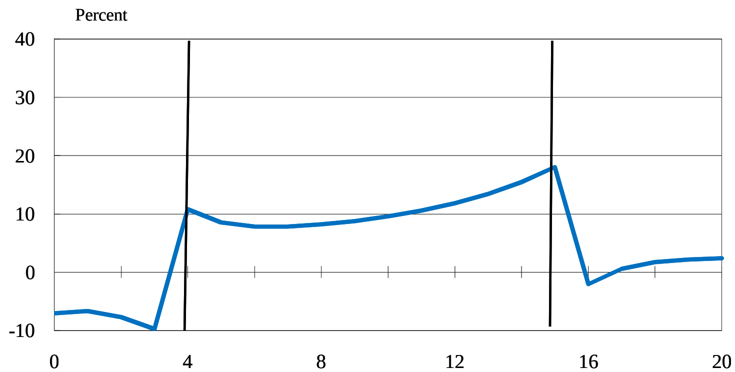
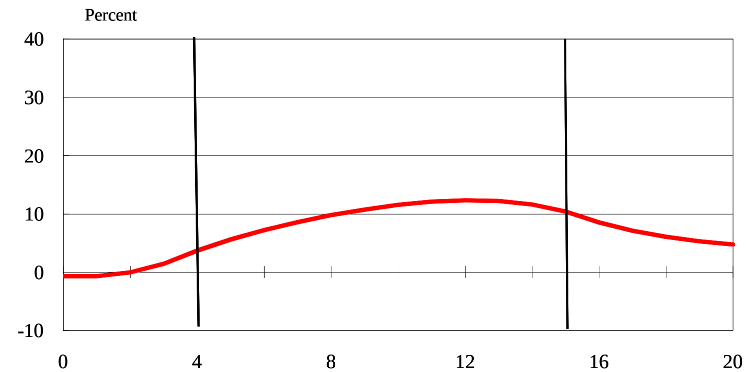


FIGURE 9.: Investment Spending Response to a Temporary Partial Expensing Allowance Anticipated in One Year's Time

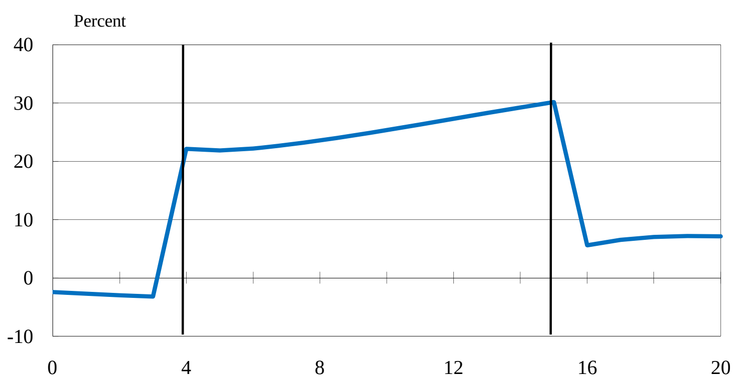
A.: Model with Sticky-prices Only
with Capital Adjustment Costs



B.: Model with Sticky-prices Only
with Investment Adjustment Costs



C.: Model with Sticky-prices and Sticky-wages
with Capital Adjustment Costs



D.: Model with Sticky-prices and Sticky-wages
with Investment Adjustment Costs

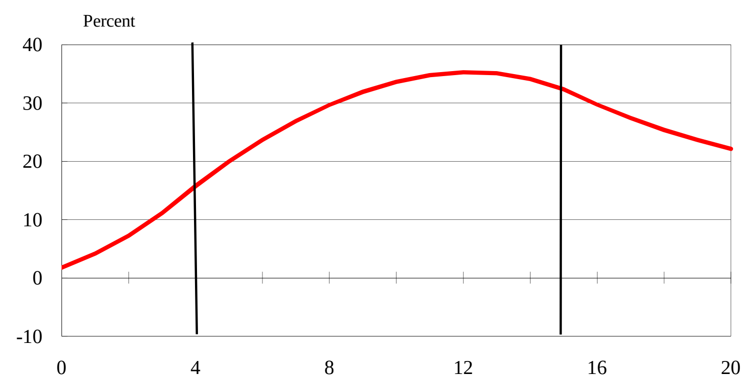
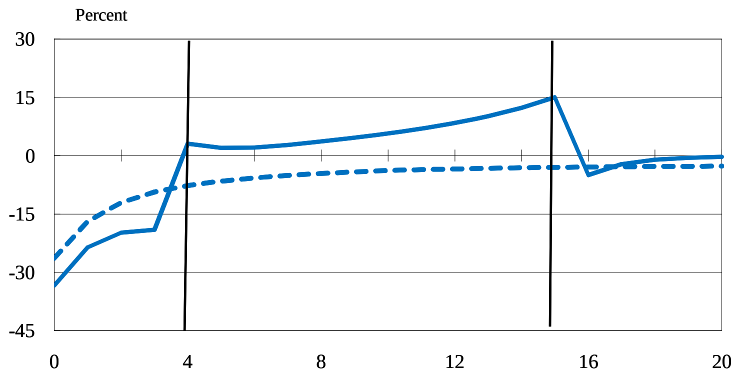
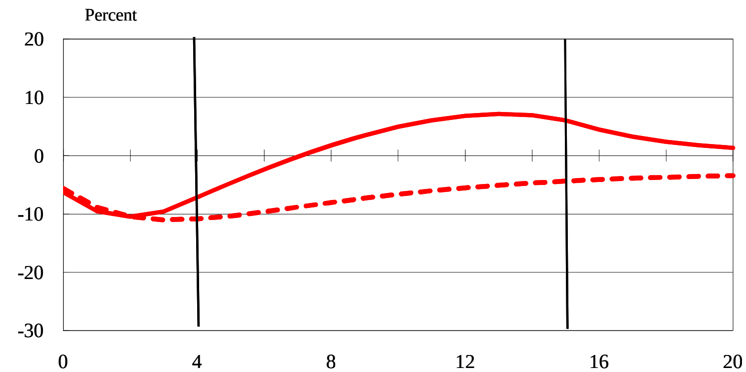


FIGURE 10.: Investment Spending Response to an Adverse Capital Efficiency Shock with (solid) and without (dotted) an Anticipated Partial Expensing Allowance Response to an Adverse Investment Spending Shock

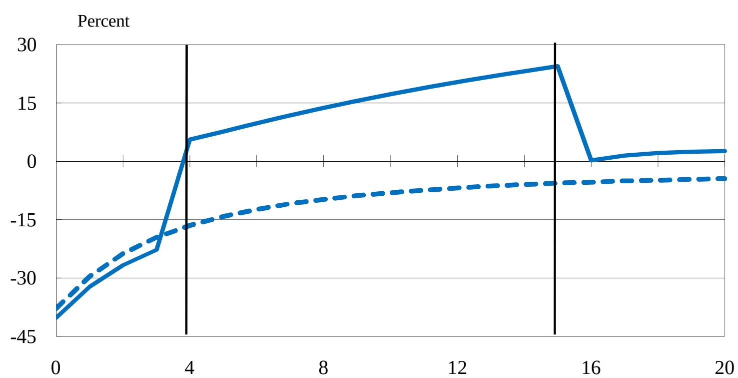
A.: Model with Sticky-prices Only
with Capital Adjustment Costs



B.: Model with Sticky-prices Only
with Investment Adjustment Costs



C.: Model with Sticky-prices and Sticky-wages
with Capital Adjustment Costs



D.: Model with Sticky-prices and Sticky-wages
with Investment Adjustment Costs

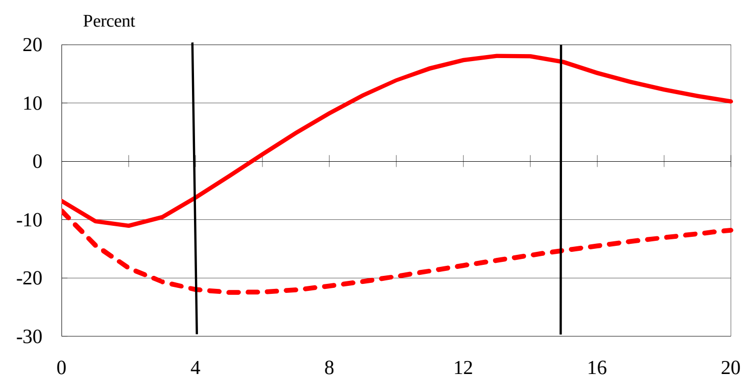
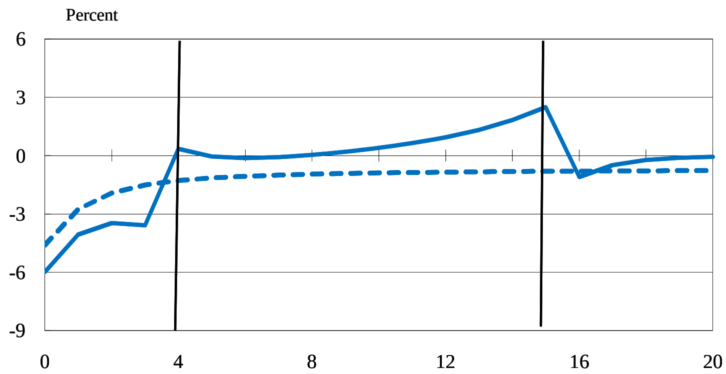
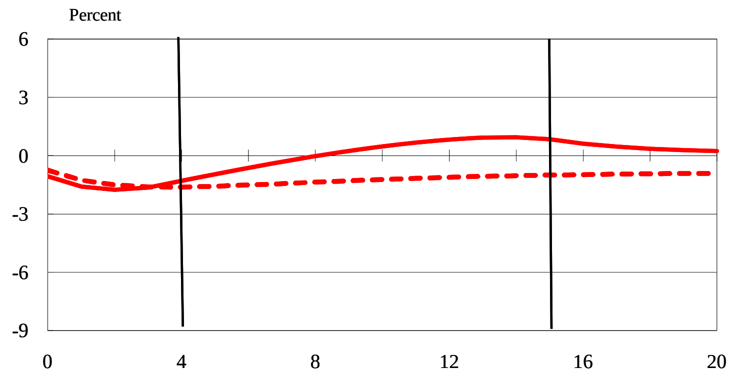


FIGURE 11.: Output Spending Response to an Adverse Capital Efficiency Shock with (solid) and without (dotted) an Anticipated Partial Expensing Allowance Response to an Adverse Investment Spending Shock

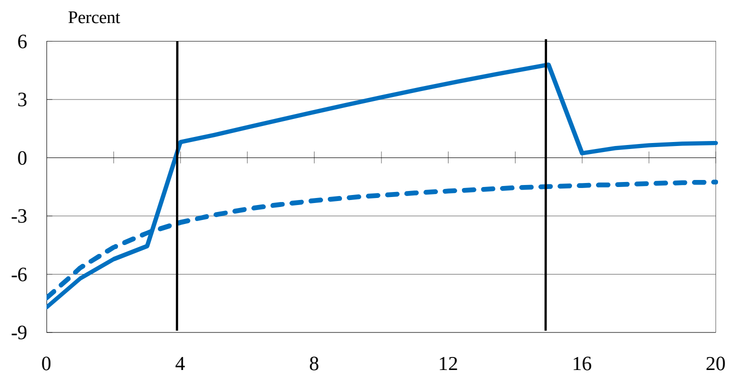
A.: Model with Sticky-prices Only
with Capital Adjustment Costs



B.: Model with Sticky-prices Only
with Investment Adjustment Costs



C.: Model with Sticky-prices and Sticky-wages
with Capital Adjustment Costs



D.: Model with Sticky-prices and Sticky-wages
with Investment Adjustment Costs

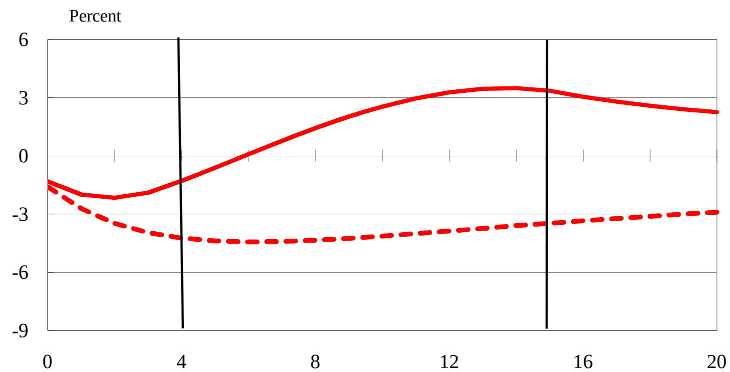
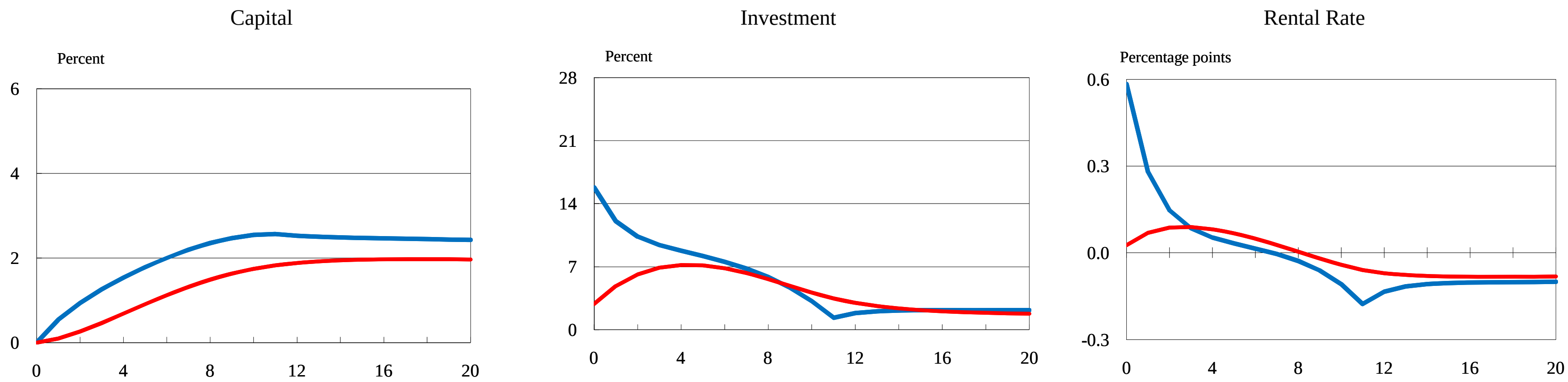


FIGURE 12.: Temporary Capital Tax Cut with Capital Adjustment Costs (blue) and Investment Adjustment Costs (red)

A.: Model with Sticky-prices Only



B.: Model with Sticky-prices and Sticky-wages

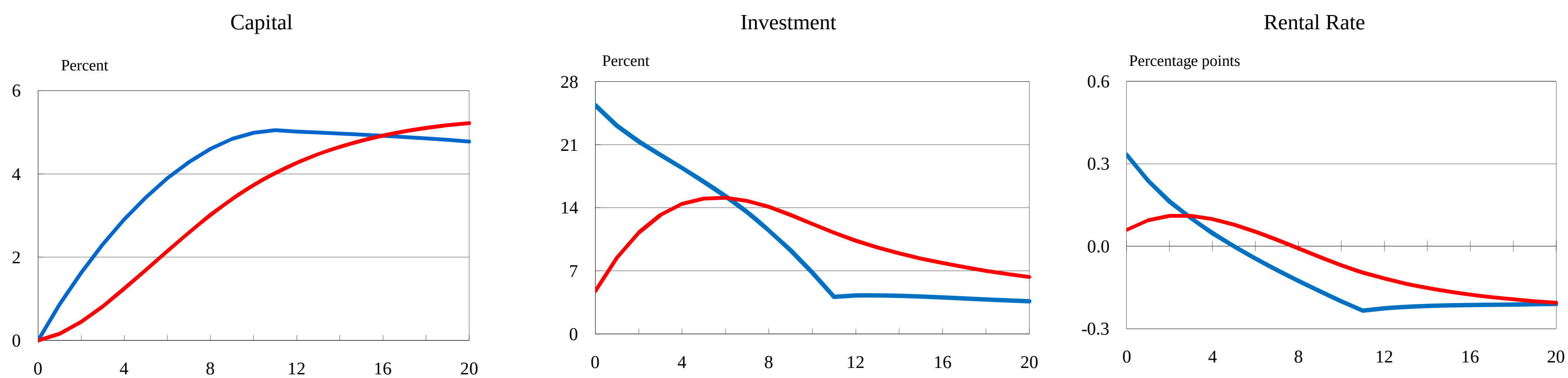
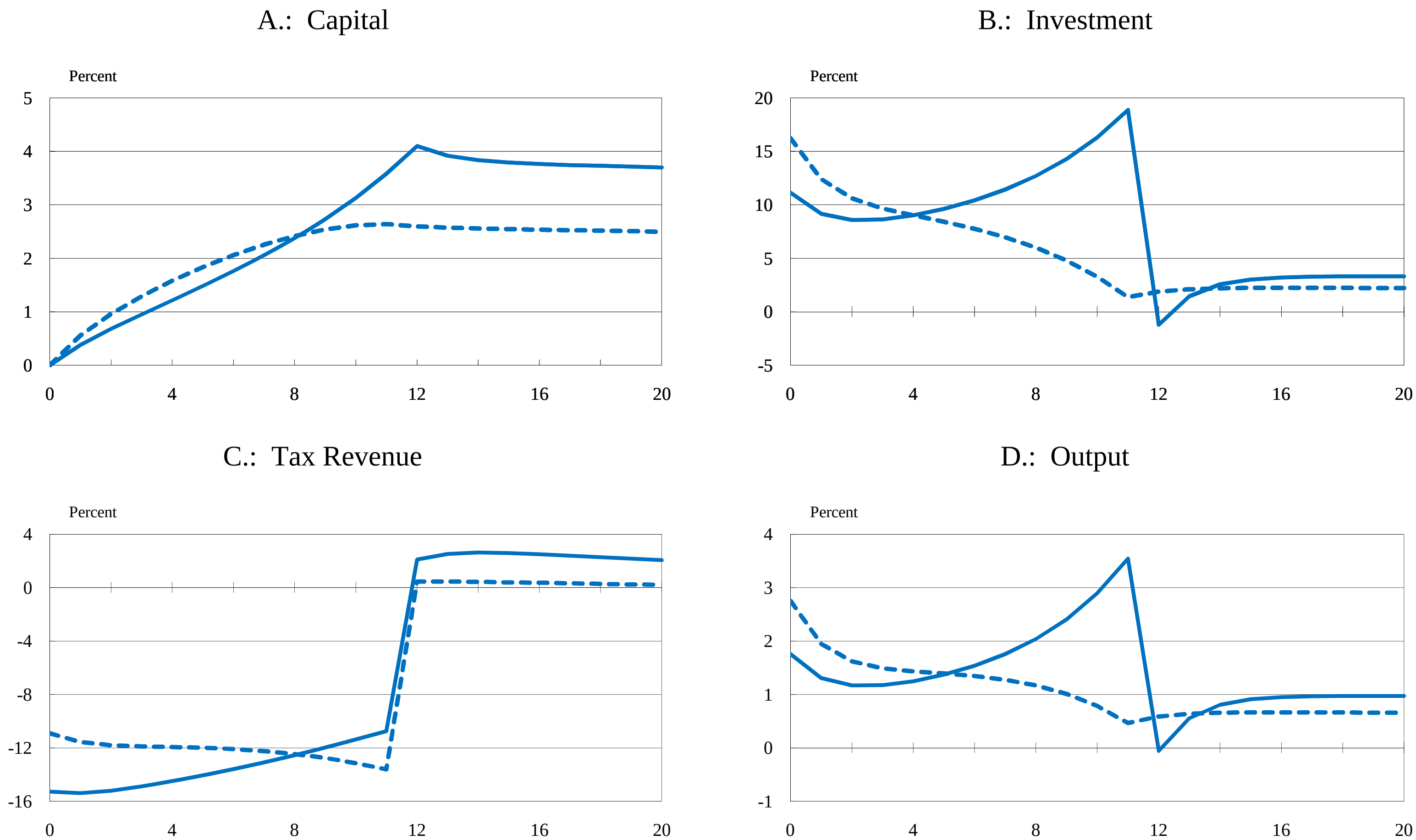
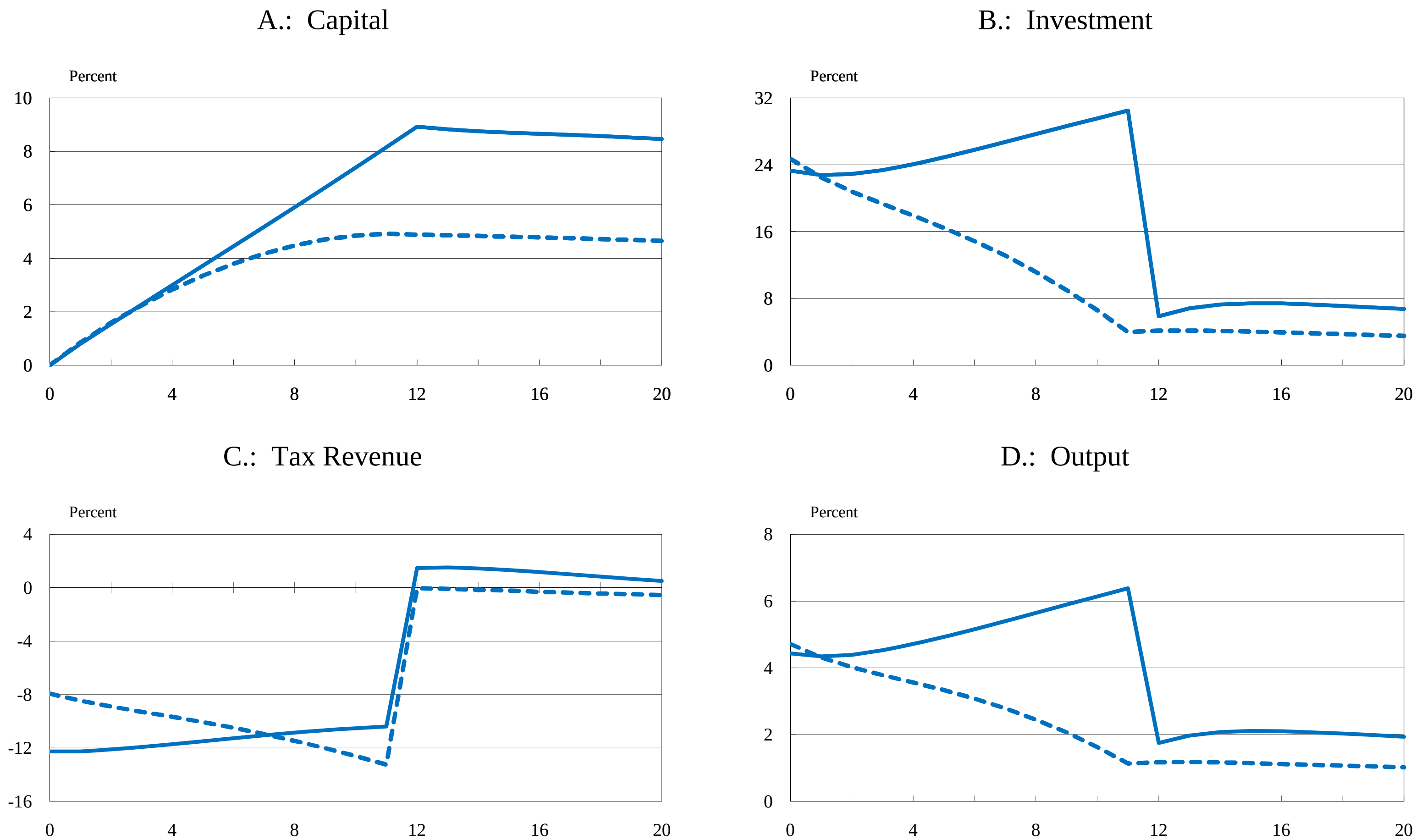


FIGURE 13.: Comparison of Two Temporary Equal-revenue Investment Incentive Policies in Sticky-price Model with Capital Adjustment Costs: A Partial Expensing Allowance (solid) and a Cut in the Capital Tax Rate (dotted)



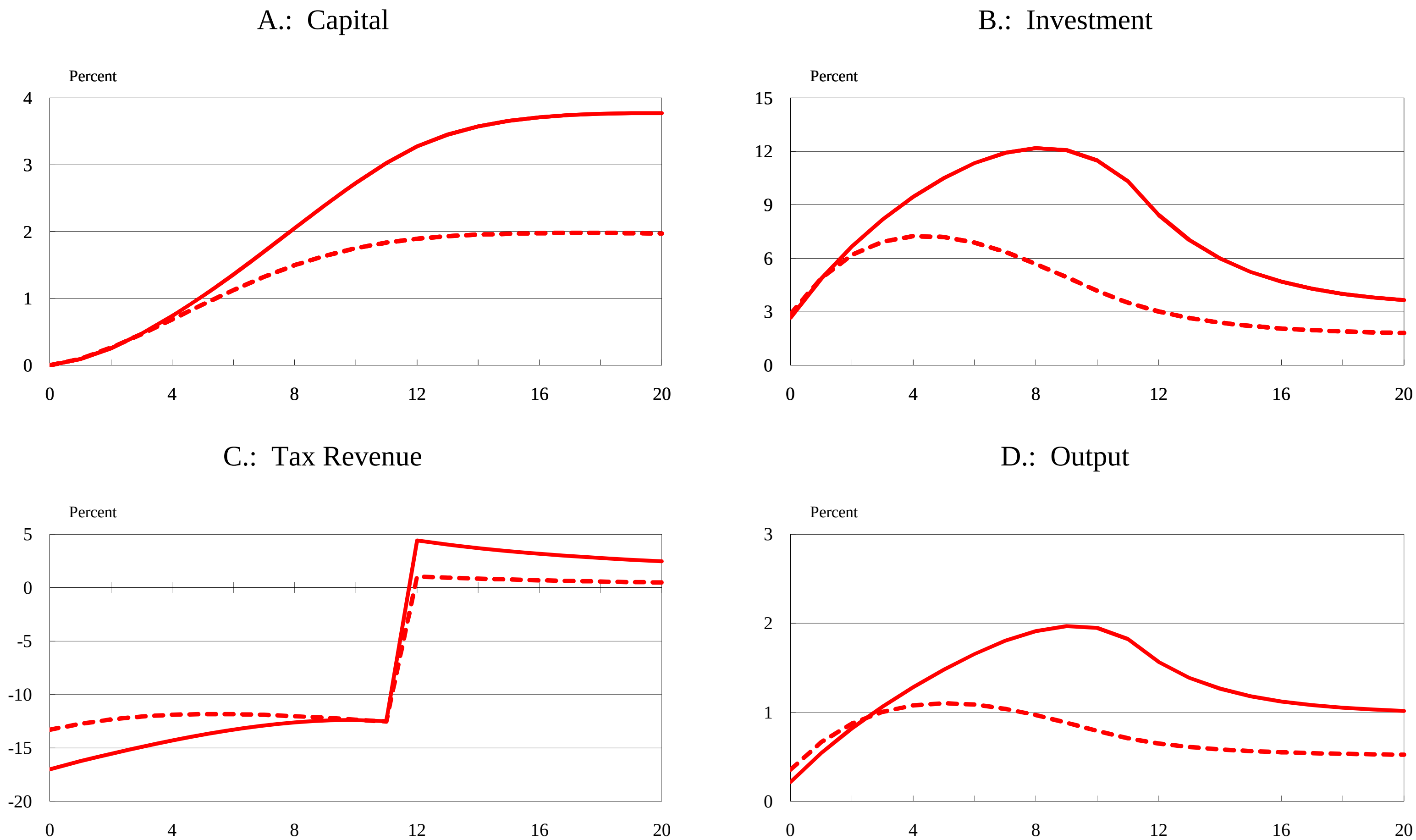
Solid line: 50 percent partial expensing allowance
Dotted line: 34.3 percentage point cut in the capital tax rate

FIGURE 14.: Comparison of Two Equal-revenue Investment Incentive Policies in Sticky-price and Sticky-wage Model with Capital Adjustment Costs: A Partial Expensing Allowance (solid) and a Cut in the Capital Tax Rate (dotted)



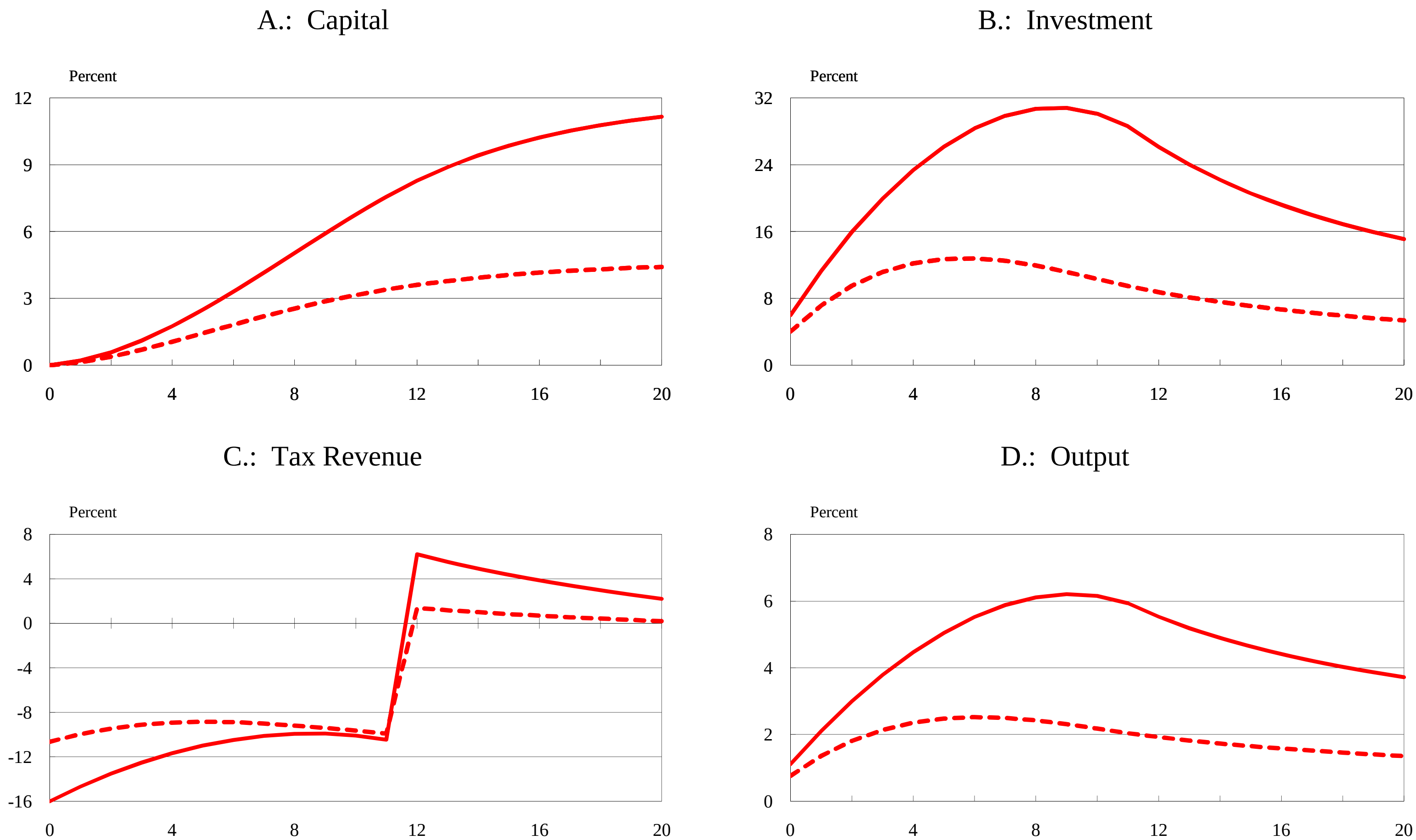
Solid line: 50 percent partial expensing allowance
Dotted line: 32.4 percentage point cut in the capital tax rate

FIGURE 15.: Comparison of Two Temporary Equal-revenue Investment Incentive Policies in Sticky-price Model with Investment Adjustment Costs: A Partial Expensing Allowance (solid) and a Cut in the Capital Tax Rate (dotted)



Solid line: 50 percent partial expensing allowance
Dotted line: 33.5 percentage point cut in the capital tax rate

FIGURE 16.: Comparison of Two Equal-revenue Investment Incentive Policies in Sticky-price and Sticky-wage Model with Investment Adjustment Costs: A Partial Expensing Allowance (solid) and a Cut in the Capital Tax Rate (dotted)



Solid line: 50 percent partial expensing allowance
Dotted line: 28.2 percentage point cut in the capital tax rate