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TEMPORARY INVESTMENT TAX INCENTIVES:
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Christopher House
Matthew D. Shapiro

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ABSTRACT

Investment decisions are inherently forward-looking. The payoff of acquiring capital goods, particularly long-lived capital goods, is governed almost exclusively by events in the far future. Because the timing of the investment itself does not affect future payoffs, there are strong incentives to delay or accelerate investment to take advantage of predictable intertemporal variations in cost. For sufficiently long-lived capital goods, these incentives are so strong that the intertemporal elasticity of investment demand is nearly infinite. As a consequence, for a temporary tax change, the shadow price of long-lived capital goods must reflect the full tax subsidy regardless of the elasticity of investment supply. While price data provide no information on the elasticity of supply, they can reveal the extent to which adjustment costs are internal or external to the firm. In contrast, the elasticity of investment supply can be inferred from quantity data alone. The bonus depreciation allowance passed in 2002 and increased in 2003 presents an opportunity to test the sharp predictions of neoclassical investment theory. In the law, certain types of long-lived capital goods qualify for substantial tax subsides while others do not. The data show that investment in qualified properties was substantially higher than for unqualified property. The estimated elasticity of investment supply is high--between 10 and 20. Market prices do not react to the subsidy as the theory dictates. This suggests either that internal (unmeasured) adjustment costs play a significant role or that measurement problems in the price data effectively conceal the price changes. While the policy noticeably increased investment in types of capital that benefited substantially from bonus depreciation, the aggregate effects of the policy were modest. The analysis suggests that the policy may have increased output by roughly 0.1 percent to 0.2 percent and increased employment by roughly 100,000 to 200,000 jobs.

Christopher House
University of Michigan
Department of Economics
238 Lorch Hall
Ann Arbor, MI 48109-1220
and NBER
chouse@umich.edu

Matthew D. Shapiro
Professor and Chair, Department of Economics
Department of Economics
University of Michigan
Ann Arbor, MI 48109-1220
and NBER
shapiro@umich.edu

I. INTRODUCTION

Even modest reductions in the after-tax cost of capital purchases provide strong incentives for increased investment. Indeed, for temporary investment tax subsidies that apply to long-lived capital goods the incentive to invest is essentially infinite. This paper presents a general equilibrium analysis of temporary changes in taxes that affect the incentive to invest. Though the paper is motivated by recent changes in tax law, the analysis has general implications for the equilibrium effects of temporary tax incentives.

Many results flow from a basic property of investment decisions: If firms are sufficiently forward-looking and investment goods are sufficiently long-lived, the elasticity of investment demand is nearly infinite with respect to temporary changes in cost. This property rests directly on the forward-looking nature of investment. Since the value of such an investment is anchored by long-run factors, variations in the timing of these investments have only minor consequences for their eventual payoffs. As a result, the decision of when to invest is highly sensitive to temporary changes in costs.

This insight leads to several results concerning temporary investment tax incentives. First, if the supply of investment goods is highly elastic in the short run, the quantity of investment will react dramatically to such policies. Second, temporary tax changes are necessarily accompanied by offsetting changes in the pre-tax shadow price of investment goods. In equilibrium the pre-tax shadow price of investment goods must move one-for-one with the tax subsidy regardless of the elasticity of investment supply.

Observing price increases following a temporary tax incentive is therefore not evidence that the supply of investment is relatively inelastic. Of course, the elasticity of investment supply does matter for the equilibrium determination of quantity. Because economic theory dictates that the underlying shadow price of investment moves one-for-one with a temporary tax subsidy, the elasticity of supply can be inferred from quantity data alone.

We test the theory by examining disaggregate investment data following the 2002 and 2003 tax bills. These bills provided temporarily accelerated depreciation, called *bonus depreciation* that allowed firms to immediately deduct an increased fraction of their investment. Under the 2002 bill firms could immediately deduct 30 percent of investment and then depreciate the remaining 70 percent under the standard depreciation schedule. Under the 2003 bill, the immediate deduction increased to 50 percent. This investment subsidy was explicitly temporary. Only investments made through 2004 qualified for this tax treatment.

Using cross-section data on investment expenditures, we estimate the elasticity of supply for investment. The data clearly show that the policy had a stimulative impact on investment in capital that benefited most from the bonus depreciation. Our estimates of the elasticity of supply are between 10 and 20. Market prices, on the other hand, show little if any tendency to increase in the short run.

We use our estimates of the supply elasticity together with the general equilibrium model to infer the likely aggregate effects of the policy. Our calculations suggest that, while their aggregate effects were probably modest, the 2002 and 2003 bonus depreciation policies had noticeable effects on the economy. For the U.S. economy as a whole, these policies may have increased GDP by $10 to $20 billion and may have been responsible for the creation of 100,000 to 200,000 jobs.

Section II presents the general equilibrium model used in our analysis. Section III presents some general results for temporary investment tax incentives and discusses their econometric implications. Section IV describes the tax changes called for by the 2002 and 2003 laws. Section V estimates the parameters of our model using the variation in the data from the policy changes. Section VI uses the model and our estimates to quantify the aggregate effects of the policy. Section VII offers our conclusions.

II. MODEL

In this section we present the general equilibrium model which we use to analyze temporary investment tax subsidies. The model allows for a general type of investment tax subsidy. Later we modify the model to consider bonus depreciation allowances like those included in the 2002 and 2003 tax bills. We use the model to present some basic properties of temporary investment tax subsidies and also to motivate our empirical research design. Later we use the model to quantify the aggregate effects of the policy. The model has a basic neoclassical structure. We begin with the household sector.

2.1 Households

Households behave competitively and maximize utility subject to their budget constraints. Households derive utility from consumption (C_t) and disutility from labor (N_t). Their utility functions take the form

$$\sum_{t=0}^{\infty} \beta^t \left\{ \frac{C_t^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} - \phi \frac{N_t^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} \right\}, \tag{1}$$

where η is the Frisch labor supply elasticity, σ is the intertemporal elasticity of substitution for consumption, and ϕ is a scaling parameter.

The households own the entire capital stock. Because the tax policies we analyze provide different incentives for different types of capital, we include several different types of capital in the model. Let $m = 1, ..., M$ be an index of capital types. For each type *m*, let δ^m be the economic rate of depreciation, and let K^m be the stock of capital. New capital goods are produced with units of the consumption good (the numeraire) as inputs. Let the total cost of producing I_t^m units of type *m* capital be $\Phi_t^m = \Phi^m\left(I_t^m\right)$. The real marginal cost of such capital is $\varphi_t^m = \varphi^m\left(I_t^m\right) = \partial\left(\Phi^m\left(I_t^m\right)\right) / \partial I_t^m$. We assume that $\varphi^m\left(I_t^m\right)$ is increasing. For the numerical simulations and for our empirical analysis we assume that the functions $\varphi^m\left(I_t^m\right)$ are given by

$$\varphi^m\left(I_t^m\right) = \left(I_t^m / \overline{I}^m\right)^{(1/\xi)}, \tag{2}$$

where $\overline{I}^m$ is the steady state level of investment for type *m* capital. Thus, the elasticity of supply is ξ and the steady state real relative price is one.[1] These costs can be interpreted as external costs which are reflected in the market price of the good or as adjustment costs which are internal to the firm and thus not reflected in the market price (Mussa [1977]).

Abstracting from many issues of corporate finance, we assume that all taxes are paid by the household. The household's labor and capital income are both subject to

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[1] Our functional form differs from Hayashi's [1982] assumptions that require zero-degree homogeneity in the investment/capital ratio. Holding the capital stock fixed one can show that, if γ is the adjustment cost parameter in the Hayashi form (i.e., $\gamma = dQ / d(I / K)$), then our elasticity is $\xi = (\gamma\,\delta)^{-1}$.

distortionary taxation. τ^N is the tax rate on labor income. Capital income is taxed twice —once as business profit and again when capital income is distributed to the households. τ^π is the tax rate on profit, and τ^d is the tax rate on the distribution of capital income (dividends and capital gains taxes).

The household chooses N_t, C_t, K_{t+1}^m, and I_t^m to maximize (1) subject to the constraints

$$(1-\tau_t^N)W_t N_t + (1-\tau_t^d)(1-\tau_t^\pi)\sum_{m=1}^{M} R_t^m K_t^m + T_t + S_{t-1}\left(1+r_{t-1}\right)$$

$$= C_t + S_t + \sum_{m=1}^{M} \Phi^m\left(I_t^m\right)\left[1-\zeta_t^m\right] \qquad (3)$$

and

$$K_{t+1}^m = K_t^m\left(1-\delta^m\right) + I_t^m, \text{ for all } m. \qquad (4)$$

Here ζ_t^m is the total effective subsidy on new purchases of type *m* capital, and includes the value of depreciation deductions and any investment tax credits.[2] W_t is the real wage. R_t^m is the real rental price of type *m* capital. I_t^m denotes investment in new type *m* capital. T_t is a lump-sum transfer. S_t is the household's holding of government debt in one-period real bonds and r_t is the real interest rate.

The household's optimization requires the first-order conditions

$$\phi N_t^{\frac{1}{\eta}} = W_t\left(1-\tau_t^N\right)C_t^{-\frac{1}{\sigma}}, \qquad (5)$$

$$C_t^{-\frac{1}{\sigma}} = \beta\left(1+r_t\right)C_{t+1}^{-\frac{1}{\sigma}}, \qquad (6)$$

$$q_t^m = \beta C_{t+1}^{-\frac{1}{\sigma}}\left[(1-\tau_{t+1}^\pi)(1-\tau_{t+1}^d)R_{t+1}^m\right] + \beta\left(1-\delta^m\right)q_{t+1}^m, \qquad (7)$$

and

$$q_t^m = C_t^{-\frac{1}{\sigma}}\varphi_t^m\left[1-\zeta_t^m\right], \qquad (8)$$

where (7) and (8) hold for all *m*. The variable q_t^m, the Lagrange multiplier on constraint (4), is the shadow value of an additional unit of type *m* capital. Equation (7) is the first-

[2] The full cost of investment is subject to the tax subsidy. Depreciation deductions are allowed for internal adjustment costs that are paid out of pocket by the firm. By law, such payments are to be depreciated along with the purchase price.

order condition for the choice of K_{t+1}^m and equation (8) is the first-order condition for the choice of I_t^m. Equation (8) relates the shadow value of capital q_t^m to the pre-tax shadow price of capital φ_t^m.[3]

2.2 Firms

Firms produce the numeraire good with a constant returns to scale production function. For simplicity we take the production function to be a generalized Cobb-Douglas form

$$Y_t = A \cdot \left[\prod_{m=1}^{M} \left(K_t^m \right)^{\gamma_m} \right]^{\alpha} \cdot \left(N_t \right)^{1-\alpha}. \tag{9}$$

Firms rent capital from the household. Each period, the firms choose K_t^m and N_t taking the rental prices R_t^m and the real wage W_t as given. Profit maximization implies that the marginal product of each input equals its marginal cost.

$$R_t^m = \alpha \gamma_m \frac{Y_t}{K_t^m}, \text{ for all } m, \tag{10}$$

$$W_t = (1-\alpha) \frac{Y_t}{N_t}. \tag{11}$$

2.3 Government Spending and Market Clearing

The government levies taxes and consumes units of the numeraire good. In our analysis, government spending G_t is constant each period. The government's intertemporal budget constraint must hold in equilibrium. This constraint is

$$\sum_{t=0}^{\infty} \frac{\tau_t^N N_t W_t - T_t - G + \sum_{m=1}^{M} \left[R_t^m K_t^m \left(\tau_t^\pi + \left(1 - \tau_t^\pi \right) \tau_t^d \right) - \tau_t^\pi \left(1 - \tau_t^d \right) \Phi^m \left(I_t^m \right) \zeta_t^m \right]}{\prod_{s=0}^{t-1} \left(1 + r_s \right)} = 0 \tag{12}$$

[3] Note that q^m is not Brainard-Tobin's Q. If adjustment costs were external, Q for type m capital would be $q_t^m / (C_t^{-\frac{1}{\sigma}} \varphi_t^m)$. Below, we argue that in response to temporary tax policies, movements in q^m are negligible. Because prices and marginal utility change in response to such policies, Q^m will change even though q^m will not.

where it is understood that $\prod_{s=0}^{t-1}(1+r_s)=1$ for $t = 0$. Like most tax changes, the policies we consider have revenue consequences. We assume that the budget is balanced with offsetting variations in the lump-sum transfers T_t. Because these transfers are lump-sum, their precise timing is irrelevant.

We require all markets to clear in equilibrium. In particular, the goods market clearing condition requires

$$Y_t = C_t + \sum_{m=1}^{M} \Phi^m\left(I_t^m\right) + G_t. \tag{13}$$

III. Temporary Investment Tax Incentives

We now present some fundamental properties of temporary investment tax incentives. This analysis sheds light on the basic economic incentives involved in such policies and motivates for our empirical analysis of the 2002 and 2003 investment policies.

Let the economy begin in the steady state. Suppose the government then credibly announces a temporary investment tax subsidy financed with variations in the lump-sum transfer *T*. The tax subsidy temporarily increases ζ_t^m for certain (or perhaps all) investment goods. The precise form of the subsidy is not important at this point; it could be an investment tax credit, a bonus depreciation allowance, etc.

3.1 Short-Run Approximations for Long-Lived Investment Goods

Although the model is complicated, two short-run approximations yield sharp, analytical results about the effects of temporary investment subsidies. The accuracy of these approximations rests on two conditions: First the policy must be temporary. Second, the approximations are most accurate for long-lived investment goods, that is, goods with low economic rates of depreciation. The approximations are less accurate and potentially quite misleading for long lasting changes in policy or for capital that depreciates rapidly.

The exact solution to the model is complicated because it has both backward- and forward-looking variables. For sufficiently temporary tax changes, it is a good approximation to replace the forward-looking variables q_t^m, and the backward-looking variables K_t^m, with their associated steady state values q^m and K^m. Replacing the capital stock with its steady state value is standard in many settings. The stock of long-lived capital is much bigger than the flow and thus changes only slightly in the short run. Specifically, the percent change in the capital stock is approximately δ^m times the percentage change in investment. (With balanced growth it would be δ^m plus the growth rate.)

The justification for approximating q_t^m with its steady state value is more subtle. Expanding equation (7), we can write q_t^m as

$$q_t^m = \beta \sum_{j=0}^{\infty} \left\{ C_{t+j+1}^{-\frac{1}{\sigma}} \left[\beta \left(1 - \delta^m \right) \right]^j \left[(1 - \tau_{t+j+1}^{\pi})(1 - \tau_{t+j+1}^{d}) R_{t+j+1}^m \right] \right\}.$$

Because the policy change is temporary, the system will eventually return to its steady state. While this may take some time, most of the terms in the brackets, particularly those in the future, remain close to their steady state values. Put differently, the difference between q_t^m and its steady state level q^m comes entirely from the first several terms in the expansion—the short-run terms. Provided that agents are sufficiently patient (i.e., that β is close to 1) and that depreciation is sufficiently slow (i.e., δ^m is sufficiently low), the future terms dominate this expression and the short-run behavior of the system has only minor influences on q_t^m.

This approximation has a natural economic interpretation. The decision to invest is inherently forward-looking. As such, the benefits from investment are anchored by future, long-run considerations. As long as the far future is only mildly influenced by temporary policies, the benefit to any given investment is independent of the short run.

3.2 Response of Investment to Temporary Tax Subsidies

In this section, we analyze the equilibrium response of the price and quantity of investment goods to temporary tax subsidies. Conventional supply and demand reasoning can be misleading because capital is durable and therefore subject to a stock demand. Expectations about the future dominate current investment decisions. Our analysis should come as no surprise to careful readers of Jorgenson [1963], Abel [1982], Summers [1985], or indeed, of Lucas's [1976] critique, which took "investment demand" as an example. As an example of how misleading conventional supply and demand reasoning can be, we show that in response to a temporary tax subsidy, the shadow price of investment goods moves one-for-one with the investment subsidy regardless of the elasticity of investment supply. This result has important econometric implications.

In our model, equation (2) gives the real pre-tax price of new type *m* capital φ_t^m which includes all of the costs of investment. It includes costs of investment that are external to the firm (the price of the good for instance) and any adjustment costs that are internal to the firm (installation costs, disruption and so forth). Figure 1 plots this equation for a single type of capital. The total pre-tax price of investment φ_t is on the vertical axis and the quantity of investment I_t is on the horizontal axis. The slope of this curve is governed by the elasticity ξ.

Equation (8) relates the shadow price of capital φ_t to its shadow value q_t, the marginal utility of resources $C_t^{-\frac{1}{\sigma}}$, and the tax subsidy $(1-\zeta_t)$. Using our short-run approximation, $q_t \approx q$, we have an equation relating the pre-tax price of investment goods to the tax subsidy and the marginal utility of consumption. Note that this equation does not involve the rate of investment. Plotting equation (8) gives a horizontal line with shift variables *C* and ζ.

The equilibrium price and rate of investment for each *m* is determined by the intersection of (2) and (8). Because $q_t \approx q$, the price can be recovered from (8) alone,

$$\varphi_t^m \approx \frac{q^m C_t^{\frac{1}{\sigma}}}{1-\zeta_t^m}, \tag{14}$$

which is independent of elasticity of supply and the quantity of investment. If the policy does not change aggregate consumption, then the shadow price of capital changes one-for-one with the subsidy. If the policy does have aggregate effects, all shadow prices move depending on the change in the marginal utility of consumption. In this case, changes in the relative pre-tax shadow prices fully reflect any differences in tax subsidies (the relative after-tax shadow prices are unchanged).[4] Thus, for temporary tax subsidies, the pre-tax price of long-lived investment goods should fully reflect the tax subsidy regardless of the rate at which the marginal costs of investment rises.

Let $\tilde{v}_t$ be the percent deviation of a variable v from its steady state value, that is, $\tilde{v}_t \equiv dv_t / v$. Then, using the constancy of q_t^m under a temporary tax subsidy, condition (8) and equation (2) imply that

$$\tilde{I}_t^m = \frac{\xi}{1-\zeta^m} d\zeta_t^m + \frac{\xi}{\sigma}\tilde{C}_t, \tag{15}$$

where $d\zeta_t^m$ is the change in the investment subsidy. If the tax subsidy has no aggregate effects, $\tilde{C}_t = 0$ so the elasticity of investment supply ξ can be inferred directly from the change in investment. If there are general equilibrium effects, one must control for the change in aggregate consumption to make this inference.

The derivation of equations (14) and (15) requires very few assumptions. Among other things, they require no reference to the production function, the marginal product of capital, or the supply and demand for labor. All that is required is a stable supply curve and the assumption that the investment is long-lived and that the policy is (sufficiently) temporary. (Equation (16) requires a particular form for the marginal utility of consumption, though this assumption can be relaxed. See Section V.) Because the structural relationships do not require many strong assumptions, our theoretical conclusions which form the basis for our econometric analysis, are robust to many different sources of misspecification.

3.3 Accuracy of the Approximation.

The approximations $q_t \approx q$ and $K_t \approx K$ are exactly true only for either arbitrarily short-lived policies or for arbitrarily low depreciation rates (and discount rates). For realistic policy durations and for real world depreciation rates, these approximations are imperfect. To evaluate the accuracy of our approximations, we present a simple example

[4] This finding has antecedents in the *Q*-theoretical investment literature, which typically considers partial equilibrium settings. Abel [1982] shows that an instantaneous, temporary tax change has no effect on after-tax *Q* (which he calls q^*). Since after-tax *Q* is constant, pre-tax *Q* fully reflects the policy change. (See also Hayashi [1982], Summers [1981, 1985], and Auerbach and Hines [1987].)

of the approximation for a variety of depreciation rates and policy durations. For simplicity we focus on a single type of capital. We take the production function to be Ak_t^{α} and we hold the real interest rate and the marginal utility of consumption constant. The firm maximizes the discounted value of after-tax profits. We assume that $r = 0.02$ (annually) and $\alpha = 0.35$. The supply of investment is given by equation (2).

Table 1 presents the equilibrium change in the shadow price of capital goods φ in response to an investment tax subsidy of one percent ($\zeta = .01$). Our approximation says that the change should be one percent (or equivalently that the change in the shadow value *q* should be zero).

Consider a long-lived capital good with an annual depreciation rate of two percent (comparable to many structures). If the elasticity of supply is 1.00 then, for a subsidy that lasts one year, the price rises by 0.993 percent. The change in the shadow value (not reported) is simply the difference between the subsidy and the price change. Thus the percent change in *q* for this case is -0.007 percent. For higher elasticities, the approximation deteriorates. If $\xi = 10$, the change in φ is 0.954 percent. As the discussion above suggests, the approximation is best for very temporary policies or very long-lived durables. Moreover, that the approximation does not hold for longer-duration policies with capital that depreciates rapidly is exactly what the theory predicts.

3.4 Implications for Observed Prices and User Cost

Price increases are a necessary accompaniment of a temporary investment subsidy. Thus, observing increased investment goods prices following a temporary tax subsidy is not evidence of a relatively inelastic supply curve. Theory suggests that the pre-tax price should rise roughly one-for-one with the investment subsidy regardless of the elasticity. Because theory has such sharp implications for the equilibrium determination of prices, it is useful to consider what conclusions, if any, could be drawn from price data.

Recall that the shadow price of investment goods reflects both external and internal marginal costs of new investment. This distinction does not matter for the determination of investment, but it does matter for relating the predictions of the model to observations in the data, which capture only market (i.e., external) prices. Let p_t^m be the market price of type *m* investment goods. We assume that internal adjustment costs in steady state are zero and that changes in the shadow cost are a reflection of changes in external and internal adjustment costs. If θ is the fraction of external adjustment costs,

$$p_t^m = 1 + \theta\left(\varphi_t^m - 1\right). \tag{16}$$

Movements in the shadow price affect market prices only to the extent that adjustment cost are external to the firm. If θ were 1 so that all investment adjustment costs were external, then we could test neoclassical investment theory by observing whether prices increased one-for-one with a temporary tax subsidy. Alternatively, without knowledge of the share of external adjustment costs, price data can be used to estimate θ. Clearly, without knowledge of θ, price data cannot be used to estimate the elasticity of supply.

Our work relates to Goolsbee's [1998] analysis of the effect of investment incentives on prices of investment goods. He finds that increases in the Investment Tax Credit (ITC) lead to increases in the price of equipment. Goolsbee concludes that the price increases indicate that the supply of investment is relatively inelastic. Our analysis leads to a different interpretation. Because the price elasticity of investment demand is essentially infinite for long-lived capital, the equilibrium price is independent of the supply elasticity. Price is determined by investment demand alone.

Often, the analysis of tax policy focuses on the user cost of capital.[5] Though the Jorgensonian user cost relationship holds in our model, it is uninformative for studying the effects of temporary investment tax subsidies. Using (6), (7) and (8), we can write the user cost expression as

$$(1-\tau_{t+1}^{\pi})(1-\tau_{t+1}^{d})R_{t+1}^{m} = \left\{ r_t + \delta^m - \left(1-\delta^m\right)\frac{\Delta\left(\varphi_{t+1}^m\left[1-\zeta_{t+1}^m\right]\right)}{\varphi_t^m\left[1-\zeta_t^m\right]} \right\}\varphi_t^m\left[1-\zeta_t^m\right], \tag{17}$$

where $\Delta\left(x_{t+1}\right) \equiv x_{t+1} - x_t$. This says simply that the after-tax marginal product of capital equals the user cost (the right had side of (17)). In certain instances (17) can be used directly to analyze the effects of policy changes. For instance, *ceteris paribus*, an increase in ζ_t^m implies a lower after tax marginal product of capital. For the marginal product to decrease, the capital stock must rise, so net investment must increase

[5] For example, Cohen, Hansen, and Hassett [2002] use this approach to analyze the potential impact of the bonus depreciation policies that we consider later in this paper. They simulate the responses to change in user cost under the assumption that prices are constant.

temporarily. Notice, however, that many assumptions are required to read the effect of the policy from expression (17). The real interest rate r_t, and the real price of new capital φ_t^m must remain constant. In addition, to the extent that the marginal product of type *m* capital interacts with other factors of production, employment and other capital inputs must also be held constant. In short, to use (17) for policy analysis requires that the policy in question has very limited (if any) equilibrium effects.

The temporary investment tax subsidies that we analyze in this paper provide a stark illustration of this point. Consider a temporary investment tax incentive that has no effect on aggregate consumption ($C_t \approx C$). For long-lived capital goods, $q_t^m \approx q^m$, which implies that φ_t^m fully reflects the tax subsidy ζ_t^m. Hence, $\varphi_t^m\left[1-\zeta_t^m\right]$ is constant and the equilibrium user cost of capital is unaffected by the policy. Equation (17) determines the demand for capital. Temporary investment tax subsidies change neither the demand for, nor the supply of, capital. Instead, they change investment, that is, the timing of when capital is acquired. For long-lived capital goods, the user cost formula provides no guidance for analyzing such policy changes.

IV. Bonus Depreciation

We use the temporary bonus depreciation allowances provided in the 2002 and 2003 tax bills to study the model's predictions. In this section we describe the normal treatment of depreciation in the U.S. Tax Code as well as the modifications provided in the 2002 and 2003 laws. We then use our model to analyze the bonus depreciation policies. Our aim is to re-derive equation (15) for the special case of bonus depreciation policy. The analysis provides the econometric relationships which we use in Section V.

4.1 The Modified Accelerated Cost Recovery System

Under the U.S. tax code, depreciation deductions for tax purposes are specified by the Modified Accelerated Cost Recovery System (MACRS). For each type of property, MACRS specifies a recovery period (*R*) and a depreciation method (200 percent declining balance, 150 percent declining balance, or straight-line depreciation.) See the appendix for more details on MACRS. The recovery period specifies how long it takes to amortize the investment. Recovery periods differ substantially across investments and are supposed to correspond roughly with the productive life of the property. Table 2 lists selected types of property and their recovery periods. The recovery period for general equipment is 7 years. Vehicles have 5-year recovery periods. Non-residential real property, which includes most business structures, is depreciated over 39-years, and so on.

4.2 Bonus Depreciation in the 2002 and 2003 Tax Bills

On March 9, 2002, the President signed the *Job Creation and Worker Assistance Act* (*JCWAA*) into effect. The most prominent provisions in *JCWAA* were intended to ease the tax burden on businesses and thereby stimulate investment. These provisions came in the form of increased depreciation allowances for certain types of business investments.

The 2002 law introduced bonus depreciation, which allowed firms to deduct 30 percent of the costs of investment from their taxable income in the first year of the recovery period. The remaining 70 percent was depreciated over the standard recovery period in accordance with MACRS. The 2003 *Jobs and Growth Tax Relief Reconciliation Act* (*JGTRRA*), signed on May 28, 2003, increased the bonus depreciation to 50 percent. Under both laws, to qualify for the bonus depreciation allowance, property had to be depreciable under MACRS and had to have a recovery period of 20 years or less. In addition, the property must have been placed in service after September 11, 2001 and prior to January 1, 2005. Firms that anticipated the policy would rationally increase investment in the third quarter in 2001.[6] We will return to the issue of the timing of the policy when we present our results.

To illustrate, suppose a business buys a car and depreciates it according to MACRS. The recovery period for cars is five years and the normal MACRS depreciation in the first year is 20 percent. The 2002 law allows the firm to first deduct 30 percent and then depreciate the remaining 70 percent according to MACRS. The deduction in the first year is then 44 percent ($30\% + .2(70\%)$).

Both the 2002 and 2003 laws included investment incentives targeted at small

[6] *JCWAA* requires that the property be *acquired* (but not necessarily placed in service) after September 11, 2004. *JGTRRA* eliminated this requirement.

businesses that complicate the analysis. Prior to *JCWAA*, the U.S. tax system allowed firms to expense investment up to $24,000 annually under Section 179 of the tax code. The 2002 law increased this limit to $25,000. The 2003 law increased the 179 exemption to $100,000 through the end of 2005. Like the bonus depreciation allowance, this exemption only applied to property with a recovery period of no more than 20 years.[7]

4.3. Quantifying Accelerated Depreciation

Hall and Jorgenson [1967] analyze depreciation allowances by assuming that the firm immediately recovers the present discounted value of depreciation deductions when it invests. For any path of depreciation deductions D_j, the present discounted value of the deductions would be

$$z = \sum_{j=1}^{R} \frac{D_j}{(1+i)^j}, \tag{18}$$

where i is the nominal interest rate. Let X be the tax reduction from purchasing a unit of investment.[8] The total tax reduction per dollar of investment from regular depreciation allowances is $X = (1-\tau^d)\tau^\pi z$. If this were the only investment subsidy, then the tax subsidy defined in Section III would be $\zeta = X$. Table 3, Panel A shows calculations of the present discounted value of depreciation deductions z for various MACRS recovery periods.

Table 3, Panel B shows the effects of the bonus depreciation policy measured as the change in z times the statutory corporate tax rate. For property with very short recovery periods, the investment subsidy is small. For five-year property the 50 percent bonus depreciation reduces the cost of investment by at most 2.88 percent. For longer recovery periods the bonus is worth more. 20-year properties get a subsidy between 5 and 10 percent with the 50 percent bonus depreciation deduction.

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[7] The bills also had other provisions. Because these provisions do not have strong effects across types of capital, we do not analyze them in this paper. For an analysis of the income tax provisions of the 2001 and 2003 tax policies, see House and Shapiro [forthcoming].

[8] The discounted value is calculated with the nominal interest rate because tax depreciation allowances are not indexed for inflation.

4.4 Modeling Bonus Depreciation

Because doing so would entail tracking the vintage structure of investment in each capital type, solving the model with the exact schedule of depreciation deductions D_j would be excessively complicated. To get a tractable, recursive representation we approximate each tax depreciation schedule with a constant geometric rate $\hat{\delta}^m$. We use this approximation again when we simulate the model in Section VI. In the econometric work in Section V, we use the exact MACRS depreciation schedules to calculate z as in equation (18).

Using the geometric approximation, MACRS without the bonus depreciation reduces the cost of investment by X_t^m where X_t^m obeys the recursion

$$X_t^m = \frac{(1-\tau_{t+1}^d)\tau_{t+1}^\pi \hat{\delta}^m}{(1+\pi)(1+r_t)} + \frac{1-\hat{\delta}^m}{(1+\pi)(1+r_t)} X_{t+1}^m \tag{19}$$

with $(1+i_t) = (1+\pi)(1+r_t)$. Note that we can write (19) as

$$X_t^m C_t^{-\frac{1}{\sigma}} = \frac{\hat{\delta}^m \beta}{1+\pi}\left\{(1-\tau_{t+1}^d)\tau_{t+1}^\pi C_{t+1}^{-\frac{1}{\sigma}} + \sum_{j=1}^{\infty}\left(\frac{1-\hat{\delta}^m}{1+\pi}\right)^j \beta^j (1-\tau_{t+j+1}^d)\tau_{t+j+1}^\pi C_{t+j+1}^{-\frac{1}{\sigma}}\right\},$$

where we have used

$$\prod_{s=0}^{j}(1+r_{t+s}) = \left(\frac{1}{\beta}\right)^j \left(\frac{C_{t+j}}{C_t}\right)^{\frac{1}{\sigma}}.$$

If the tax depreciation rate on type *m* capital is sufficiently low, and if the policy is temporary, arguments like those in Section III permit us to approximate $X_t^m C_t^{-\frac{1}{\sigma}}$ with

$$X_t^m C_t^{-\frac{1}{\sigma}} \approx C^{-\frac{1}{\sigma}} \tau^\pi (1-\tau^d) z^m. \tag{20}$$

Let λ_t^m denote a bonus depreciation allowance for type *m* capital. As in the actual legislation, for every dollar of investment in such capital, firms write off λ_t^m immediately and the remaining $(1-\lambda_t^m)$ is depreciated according to the usual depreciation schedule. The total subsidy on investment in type *m* capital ζ_t^m is then

$$\zeta_t^m = \lambda_t^m \tau_t^\pi \left(1-\tau_t^d\right) + \left(1-\lambda_t^m\right) X_t^m. \tag{21}$$

This calculation relies on the assumption that firms pay at least some income tax. Furthermore, as long as the firm is not exclusively debt financed, the subsidy is effective. That is, the analysis is unchanged even if the marginal investments are debt financed.

Using (20) and our short-run approximations for *q* and *K*, we can write (15) as

$$\tilde{I}_t^m = \xi\left(\frac{\tau^\pi(1-\tau^d)(1-z^m)}{1-\tau^\pi(1-\tau^d)z^m}\right)d\lambda_t^m + \frac{\xi}{\sigma}\left(\frac{1}{1-\tau^\pi(1-\tau^d)z^m}\right)\tilde{C}_t. \tag{22}$$

The first term is the direct change in investment due to bonus depreciation. As before, the second term captures the extent to which the policy has aggregate effects. If bonus depreciation applies broadly, employment will increase (because the policy effectively increases the real wage) and consumption will decrease (as households substitute toward subsidized investment).[9]

The real relative prices of investment goods are also affected by the policy. Because $\tilde{\varphi}_t^m = (1/\xi)\tilde{I}_t^m$, the pre-tax shadow price of type *m* capital is

$$\tilde{\varphi}_t^m = \left(\frac{\tau^\pi\left(1-\tau^d\right)\left[1-z^m\right]}{\left(1-\tau^\pi(1-\tau^d)z^m\right)}\right)d\lambda_t^m + \left(\frac{1}{\sigma}\right)\left(\frac{1}{\left(1-\tau^\pi(1-\tau^d)z^m\right)}\right)\tilde{C}_t. \tag{23}$$

As in Section III, this equation is independent of the elasticity of the supply of investment goods. The first term is the discounted value of the tax subsidy itself. In the absence of changes in $\tilde{C}_t$, the shadow price of investment goods increases one-for-one with the tax subsidy.

Equations (22) and (23) can be used to illustrate the predicted effects of bonus depreciation. Figure 2 plots deviations in investment and real relative prices implied by (22) and (23) against the tax depreciation rate for ten different types of capital goods for the quarters immediately after the legislation: 2002:2 and 2003:3. To generate the

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[9] Typically increases in wages have offsetting income and substitution effects. In this case however, the temporary nature of the policy together with the forward looking behavior of the household implies that the income effect is negligible (a fact embodied in our short-run approximations). Using (5), (9), (11), (13), and (22) one can show that the change in employment is approximately

$$\tilde{N}_t = \frac{\xi\cdot\sum_{m=1}^{M}\frac{I^m}{Y}\left(\frac{\tau^\pi(1-\tau^d)(1-z^m)}{1-\tau^\pi(1-\tau^d)z^m}\right)d\lambda_t^m}{(1-\alpha)+\sigma\left(\frac{1}{\eta}+\alpha\right)\left\{\frac{C}{Y}+\frac{\xi}{\sigma}\sum_{m=1}^{M}\frac{I^m}{Y}\left(\frac{1}{1-\tau^\pi(1-\tau^d)z^m}\right)\right\}} \geq 0.$$

The inequality is strict as long as $\tau^\pi < 1$, $\sigma < \infty$, $\eta > 0$ and as long as $z^m < 1$. The first-order approximation of condition (5) then gives $\tilde{C}_t = -\left(\eta^{-1}+\alpha\right)\sigma\tilde{N}_t \leq 0$.

figures, we chose parameter values for τ^{π}, τ^{d} and σ and calculated z^m for each type of capital according to the approximate MACRS tax depreciation rates. We set $\tilde{C}_t$ to −0.054 percent in 2002:2 and −0.077 percent in 2003:3. (These parameter values and changes in consumption are taken from the simulations of the model presented in Section VI.) We used the bonus depreciation rates λ_t^m provided by the law and set ξ to 15 which is roughly the midpoint of the estimates we get in the next section. In Figure 2, each point represents the log deviation from steady state of a particular type of capital. Solid circles indicate capital types that qualify for bonus depreciation. Empty circles indicate capital types that do not qualify.

The top panels show the changes in real investment spending immediately after the 2002 and 2003 laws go into effect. Properties with the lowest tax depreciation rates do not qualify for the depreciation allowance. Because of the small aggregate effects of diverting resources to investment in qualified capital, investment in unqualified types falls slightly. Investment jumps up sharply for 20-year property, the qualified capital with the lowest tax depreciation rate and therefore the highest benefit from the bonus. Since the tax subsidy decreases as the tax depreciation rate increases, investment in qualified capital declines steadily as a function of tax depreciation rates. The lower panels graph the changes in real shadow prices against the tax depreciation rates. The response is the same as for quantity except for scaling by the elasticity of supply.

V. Empirical Analysis of Bonus Depreciation

We use data on real investment spending and real investment prices to estimate the parameters of equations (22) and (23). The estimates yield a value for the elasticity of supply (ξ) and allow us to test whether investment prices reflect the tax subsidy.

5.1 Data

We use data from the BEA to construct a quarterly panel of investment quantities and prices by type. We match the BEA investment data to IRS depreciation schedules. Once we exclude BEA types that do not have clear matches to the IRS depreciation schedules, our panel has 36 types of capital with quarterly observations from 1959 to 2005.[10] We construct real investment purchases by dividing nominal purchases of type *m* capital by the price index for that type. The relative price for type *m* capital is defined as the *m*th price index divided by the GDP deflator. (The appendix provides more information on this data. See Appendix Table 2 for a list of the capital goods in our data set.)

For our econometric procedure we also use aggregate data on GDP and corporate profits and data on type-specific investment tax credits.[11] Finally, equations (22) and (23) require the cyclical component of aggregate consumption $\tilde{C}_t$. For this series, we use HP-filtered real consumption of nondurables and services with a quarterly smoothing parameter of 1600.

5.2 Econometric Specification and Estimation

Equations (22) and (23) show how investment quantities and prices respond to bonus depreciation. Before turning our attention to these structural equations, we first need to estimate what investment and prices would have been in the absence of the policy. We use several decades of data prior to the policy to forecast investment quantities and prices for each type of capital. The resulting forecast errors serve as data for the structural equations (22) and (23).

The forecasting equations we use to project investment quantity and price are reduced forms. Our theory does not mandate what variables to include. Our aim is simply to control for major determinants of investment quantities and prices unrelated to the policy we are studying. We construct forecasts for horizons $h = 1 \ldots H$ using forecasting equations of the form

$$\ln\left(I_{t+h}^{m}\right) = B_I^{h,m} Z_t^m + \varepsilon_{I,t}^{h,m} \tag{24}$$

and

$$\ln\left(p_{t+h}^{m}\right) = B_p^{h,m} Z_t^m + \varepsilon_{p,t}^{h,m} . \tag{25}$$

[10] The BEA made changes to its series on private domestic investment in 1997. We therefore use investment categories that were consistent before and after 1997. We exclude steam engines from the analysis because it is a consistent outlier. The point estimates we report are similar with or without steam engines.
[11] We are grateful to Dale Jorgenson for providing us with the data on the ITC by capital type. These data are constructed using methods detailed in Jorgenson and Yun [1991].

I_{t+h}^{m} and p_{t+h}^{m} are the investment quantity and price for horizon *h* and type *m* capital. The vector Z_t^m includes the variables we use to construct the forecasts. $B_I^{h,m}$ and $B_p^{h,m}$ are the corresponding parameters. Since (24) and (25) are simply auxiliary forecasting equations, we are fairly agnostic about their specification. Our baseline specification for the forecast equations includes the *t* and $t-1$ values of the following variables: investment quantity and prices, the log of aggregate real GDP, the corporate profit rate, and the type-specific Investment Tax Credit. It also includes a constant and a time-trend. As a parsimonious alternative, we also consider forecasting equations with only the constant and time trend in Z_t^m.

We estimate (24) and (25) over the sample period $t = 1,...,T$ = 1965:1 to 2000:4.[12] We then use these equations to project investment quantities and prices over 2001:1 to 2005:4. Because our forecasts for this period all condition on the same information (i.e., information at date *t* = 2000:4), we can suppress the subscript *t* and write the forecast errors as $\hat{\varepsilon}_I^{h,m}$ for investment and $\hat{\varepsilon}_p^{h,m}$ for prices. Each $h = 1,\ldots,H$ corresponds to a quarter between 2001:1 and 2005:4 (*h* = 1 is 2001:1).

We now estimate (22) and (23) with the forecast errors as the left-hand-side variables. Define Ψ_1^m and Ψ_2^m as

$$\Psi_1^m = \frac{\tau^{\pi}\left(1-\tau^{d}\right)}{\left(1-\tau^{\pi}(1-\tau^{d})z^{m}\right)}\left[1-z^{m}\right] \text{ and } \Psi_2^m = \frac{1}{\left(1-\tau^{\pi}(1-\tau^{d})z^{m}\right)}.$$

These parameters are constant across time, but differ across types of capital *m*. Calculating Ψ_1^m and Ψ_2^m requires values for τ^{π}, τ^{d} and z^m which are observable. Referring back to equation (22), our model implies

$$\hat{\varepsilon}_I^{h,m} = \beta_{I0} + \xi\lambda_h^m\Psi_1^m + \frac{\xi}{\sigma}\Psi_2^m\tilde{C}_h + e_I^{h,m} \qquad (26)$$

where β_{I0}, ξ, and ξ/σ are parameters to be estimated, and $e_I^{h,m}$ is an error unrelated to the change in the policy. The bonus rate λ_h^m is 0.3 or 0.5 for eligible capital during

[12] For computer equipment, the estimation period begins in 1970:1.

2002:2 to 2004:1 and zero otherwise (i.e., $\lambda_h^m = 0$ for ineligible capital and for all capital prior to 2002:2 and after 2004:1). The corresponding version of (23) is

$$\hat{\varepsilon}_p^{h,m} = \beta_{p0} + \beta_{p1}\Psi_1^m \lambda_h^m + \frac{1}{\sigma}\Psi_2^m \tilde{C}_h + e_p^{h,m}. \tag{27}$$

If investment adjustment costs were entirely external (and thus included in measured prices) then the estimate of β_{p1} should be one. Since adjustment costs may be partially internal, any value of β_{p1} between zero and one is consistent with the theory.

At a fundamental level, variation in tax policy across types and across time identifies the structural parameters in the model. Investment also influenced by aggregate conditions. Equations (26) and (27) show that the response to aggregate conditions varies systematically across the type of capital. According to the model, the appropriate control variable is marginal utility times Ψ_2^m. To control for aggregate conditions, we consider two measures of marginal utility. First, we use a specification based on our model. In the model, marginal utility is proportional to $\tilde{C}_h$ (HP-filtered consumption of nondurables and services). Thus our first specification includes $\Psi_2^m \tilde{C}_h$ as a control variable. Our second method allows for the possibility that marginal utility is poorly-proxied by filtered consumption. We replace the consumption-based measure of marginal utility with time-dummies scaled by the same type-specific factors. That is, in this specification of equation (26), the term $\xi\sigma^{-1}\Psi_2^m \tilde{C}_h$ is replaced by $\sum_{k=1}^{H} \beta_k \Psi_2^m d_{h,k}$ where β_k are parameters that subsume $\xi\sigma^{-1}\tilde{C}_k$ and $d_{h,k} = 1$ if $h = k$ and zero otherwise (i.e., $d_{h,k}$ are time-dummy variables) . We make a similar substitution for equation (27). These estimates treat the marginal utility of consumption as an unobserved time-varying object that is common across investment types. Obviously using time-dummies, the parameter σ is not identified.

The disturbances $e_I^{h,m}$ and $e_p^{h,m}$ are not independently and identically distributed. Let Ω_i and Ω_p be the $HM \times HM$ covariance matrices for the disturbances $e_I^{h,m}$ and $e_p^{h,m}$. There are three important features of these covariance matrices. First, within type, the forecast errors are likely correlated across time. Second, there is substantial heteroskedacity across types because some types are less predictable than others. Finally, there is correlation across types because certain investment goods react to common shocks in systematic way.

Clearly, with 36 types ($M = 36$) and 20 periods, ($H = 20$), we cannot estimate the parameters of these matrices as each has more than 270,000 independent parameters. Instead, we impose some additional structure on Ω_I and Ω_p. To pool the types across time, we assume the covariance matrices have the following structure

$$\Omega_I = R_I \otimes \Sigma_I \text{ and } \Omega_p = R_p \otimes \Sigma_p . \tag{28}$$

R_I and R_p are $H \times H$ matrixes giving the correlation of the disturbances across time within a type. Σ_I and Σ_p are $M \times M$ matrices giving the covariance across types for a given time. The (h, h') element of R_I and R_p can be estimated consistently by

$$r^I_{h,h'} = \frac{1}{M}\sum_{m=1}^{M}\frac{s^{m,I}_{h,h'}}{s^{m,I}_{1,1}} \;,\; r^p_{h,h'} = \frac{1}{M}\sum_{m=1}^{M}\frac{s^{m,p}_{h,h'}}{s^{m,p}_{1,1}} , \tag{29}$$

where $s^{m,I}_{h,H}$ and $s^{m,p}_{h,H}$ are the sample covariances of the residuals from equations (24) and (25) respectively. Similarly, Σ_I and Σ_p are the sample covariance matrices of the residuals of (24) and (25) for horizon $h = 1$. These calculations provide consistent estimates of Ω_I and Ω_p that we use to provide correct standard errors for our structural parameter estimates.

We do not use the full covariance structure to estimate the structural parameters, so our parameter estimates are robust to misspecification of Ω_I and Ω_p. We estimate (26) and (27) by ordinary least squares (OLS) and also by weighted least squares (WLS) using the inverses of the diagonals of Ω_I and Ω_p as weighting matrices. The WLS estimates improve the efficiency of the estimates in light of the strong heteroskedacity in the forecast errors across types.[13]

[13] See Appendix A.5 for more details on our estimation procedure. Our specification differs from the standard two-step procedure because we estimate the covariance matrix over a large sample (1965-2000) and then use them to adjust our structural estimates in a separate, subsequent data set (i.e., 2001-2004). Similarly, there is nothing to be gained from estimating the forecasting equations (24) and (25) jointly with the structural equations (26) and (27).

5.3 Results

5.3.1 Scatterplots

Before turning to the structural estimates of (26) and (27), it is instructive to plot the data. Figure 3 shows the log forecast errors from the baseline forecast specification. Each panel represents a time period. The tax depreciation rates are on the horizontal axes. The panels on the top row show the forecast errors for real investment while the lower panels show the forecast errors for real relative prices. These plots correspond to the theoretical plots shown in Figure 2. Each point in the figure is the forecast error for a single quarter and a single type of capital. Since each panel includes multiple quarters, there are several observations per type. Solid points are types that qualify for bonus depreciation. Empty circles are types that do not qualify. We group the data into five time periods. The first period, 2001:1 to 2001:3, was before the policy was discussed or in effect. The second period, 2001:4 to 2002:1, was before the policy was law but during which the policy applied retroactively. We refer to the second period as the *anticipation period*. The third and fourth periods, 2002:2 to 2003:2, and 2003:3 to 2004:1 correspond to the periods of the 30 and 50 percent bonus. The last period, 2005:1 to 2005:4 is after the policy expired.

Consider that data for investment quantity shown in the top row of Figure 3. As one would expect, in the first period (before the policy), there is no discernable relationship between the tax depreciation rate and investment forecast errors. In the anticipation period, the pattern predicted by the theory is clearly evident. There is a sharp discontinuity between eligible property and ineligible property and there is a negative relationship between the tax depreciation rate and investment among qualified properties. This pattern remains in the third and fourth panels. In the fifth panel, after the expiration of the policy, the data do not clearly return to normal. The negative relationship among qualified types is not clear, but the discontinuity between unqualified types and qualified types with low tax depreciation rates persists into 2005.

Overall, comparing the actual forecast errors for real investment in Figure 3 with the simulated data in Figure 2 suggests that the tax policy had the predicted effects. In Section 5.4 we discuss the expiration of the policy in 2005.

The bottom row of Figure 3 shows the same plots for the price data. Unlike the quantity data, there is no discernable pattern of price movements across types of capital or across time periods. The variability in the forecast errors suggests that it is not going to be possible to test the theory using these data. We will confirm this below in the econometric analysis.

5.3.2 Structural estimates of elasticity of supply

We now turn to the structural estimates of equations (26) and (27). We fit these equations with the data plotted in Figure 3. The left-hand side variables are the forecast errors and the explanatory variables are as defined in the equations. For these estimates, the timing of the policy corresponds to the signing dates and the expiration date provided by the law. Thus the 30 percent bonus goes into effect in 2002:2, the 50 percent bonus goes into effect in 2003:3 and the policy expires in 2005:1.

Table 4 shows the estimates of the structural parameters. Panel A gives the estimates of the investment equation (26). The rows give alternative macroeconomic controls in the forecasting and structural equations. In row 1 of Panel A, the baseline forecast specification, the WLS estimate of ξ is 11.64 with an adjusted standard error of 2.55. The OLS point estimate is similar, but with a somewhat larger standard error. (The comparison of OLS and WLS is similar for all specifications, so we discuss only the more efficient WLS estimates.) As expected, the standard errors in the specification with only a time trend (rows 2 and 4) are larger because the forecasts are less precise.[14] Lines 3 and 4 of Panel A, give the estimates for the specification where the scaled time-dummies replace the consumption-based measure of marginal utility as the control for the aggregate effects of the policy. The point estimates for ξ are uniformly higher—21.84 in the baseline forecast specification.

The econometric estimates quantify what was evident from Figure 3. There is a powerful response of the quantity of investment to the bonus for types of capital that

[14] We experimented with several alternative specifications of the forecasting equations. The results were not sensitive to these alternatives. Among the alternatives was a specification including *contemporaneous* GDP and profits in (24) and (25) to control for systematic cyclical responses of investment. The resulting change in our point estimates was negligible.

benefited substantially from the bonus. The strong movements in quantity yield high estimates of the elasticity of supply—ranging between 11 and 21.

5.3.3. Structural estimates of implied bonus rate

In the estimation presented in Table 4, λ_h^m is a known parameter of the tax policy—equal to 0.3 or 0.5 for eligible capital during the period of the bonus and zero otherwise. The exact timing of the bonus in these estimates is assumed to match with the enactment in law, that is, zero prior to 2002:2 and after 2004:4. Alternatively, we can estimate the time series of implied the bonus rates that best fits the cross-section of investment period-by-period. To do so, we relax the constancy of the response to the bonus across time imposed in equation (26) and estimate the equation

$$\hat{\varepsilon}_I^{h,m} = \beta_{I0} + \sum_{k=1}^{H} \Lambda_k \xi \Psi_1^m d_{h,k} B^m + \frac{\xi}{\sigma} \Psi_2^m \tilde{C}_h + e_I^{h,m} . \quad (30)$$

Here Λ_k is the implied bonus rate for period *k* and $d_{h,k}$ is again a time-dummy equal to one when *h* = *k* and zero otherwise. B^m equals one for types eligible for the bonus and zero otherwise. Since the implied bonus and the elasticity of supply cannot be identified separately, in equation (30) we set ξ at a fixed value of 21, roughly the upper bound on the estimates in Table 4. Figure 4 plots the estimates of Λ_h, the implied bonus rate. The dotted lines are one-standard-error bands. The thin solid line is the time path of the statutory bonus depreciation rate (dashed during the retroactive/anticipation period). As in Table 4, we consider specifications with either aggregate consumption (top panel) or scaled time-dummies (bottom panel) to control for aggregate effects.

The implied bonus rate in the upper panel of Figure 4 closely tracks the actual bonus rate. The estimates are close to zero in early 2001, but then jump in mid- to late-2001. This finding is consistent with a credible anticipation of the enactment of the retroactive policy. The implied bonus tapers off throughout 2003 and 2004. Empirically, this means that the differential increase in investment in types of goods benefiting most from the bonus is diminishing. By 2005, when the bonus has expired, the implied bonus is approaching zero.

The diminishing effect of the policy in the upper panel of Figure 4 is not clearly evident in the scatterplots in Figure 3. Indeed, when we re-estimate (30) using Ψ_2^m-scaled time-dummies instead of $\Psi_2^m \tilde{C}_t$, the effects of the policy seem to persist even throughout 2005. The lower panel of Figure 4 plots the implied bonus rate for this specification. Looking back to Figure 3, it is clear that the evidence for 2005 is mixed. It is therefore not surprising that our estimates also yield mixed results on this point.

5.3.4 Structural estimates of response of price of investment

We now turn briefly to the structural estimates for the response of observed investment prices to bonus depreciation. It is clear from the scatterplots in Figure 3 that the sharp pattern exhibited by the quantities is not present in the price data. Table 4, Panel B, reports the structural estimates of equation (27). The theory implies that the shadow price of capital should change one-for-one with the tax subsidy. If all adjustment costs were external, and thus reflected in the purchase price, then β_{p1} in equation (27) should be one. If a fraction θ of adjustment costs are internal, then β_{p1} should reflect this fraction. In the table, the point estimates of β_{p1} are negative, and have large standard errors. The standard errors are so large that we can reject neither 1 (pure external adjustment costs) nor 0 (pure internal adjustment costs). Time-varying estimates for the price data analogous to Figure 4 (not reported) similarly show uniformly negative point estimates with wide confidence intervals.

It is not too surprising that we cannot detect the effect of the policy in the price data. Even if adjustment costs were completely external, price changes of this magnitude would be difficult to detect. The calculations in Table 3, Panel B indicated that the value of the subsidy was at most 5 to 8 percent. Thus we should expect prices to rise by no more than 8 percent for the most heavily subsidized goods. Such price changes are small relative to the standard deviation of forecast errors for prices (roughly 10 to 20 percent during the period 2002:2 to 2004:4). Thus, while price data can, in theory, provide a good test of the model, in practice, the price data is simply too noisy to permit such an assessment. In contrast, the quantity of investment of eligible types responds by many times the value of the subsidy. Of course, this is why we estimate a high elasticity of supply.

5.4 Discussion

Our research design uses two exogenous dimensions of variation in the data—the differential value of the bonus depreciation allowance across type and the time-series variation of the policy. While the cross-sectional investment data strongly supports basic predictions of the model, the evidence from the timing of the changes, though generally supportive of the theory, is not as sharp. Indeed, the data indicate that investment reacted prior to the signing of the bill and that the expiration of the policy was not clear in the data. We deal with the anticipation and expiration of the policy in turn.

Our scatterplots and econometric analysis clearly show that the effects of bonus depreciation were evident prior to its enactment. While the bill was not signed until March 2002, there were clear signals in the preceding months that such legislation would be passed. The Economic Security and Recovery Act of 2001 was passed by the House on October 24 and included the depreciation provisions.[15] It is standard to make changes in tax provisions retroactive because it is well-understood that failing to do so creates incentives to delay economic activity. Usually, provisions are retroactive to date of a law is introduced but in this case, the Congress chose the symbolic date of September 11, 2001. The continuing slow recovery of the economy from the 2001 recession made the eventual passage of the legislation relatively certain.[16] Hence, it seems reasonable that the apparent anticipation of the policy in 2001:4 and 2002:1 in our results are genuine responses of firms to the policy rather than a fluke of the data.

The expiration of bonus depreciation occurred on schedule at the end of 2004. While our structural estimates depend critically on the public's belief that the policies would expire, as long as there was some probability that the policy would expire, firms

[15] The depreciation provisions were the first items in the bill (see Joint Tax Committee, October 11, 2001). These provisions—including the retroactivity to September 11, 2001—survived intact from the Ways and Means Committee's markup on October 12, 2001 to the bill as finally enacted.

[16] "While it has gotten little attention, the so-called bonus depreciation is the one corporate tax break sure to become law." *Boston Globe* (December 7, 2001) p. E1.

still had a powerful incentive to invest prior to 2005.[17] Our evidence on the expiration is mixed. Neither the scatterplots in Figure 3 nor the time varying implied bonus rate in Figure 4 provide clear evidence of the expiration. Moreover, in the top panel of Figure 4, the implied bonus peaked well before the expiration of the policy. Several important factors likely contribute to the lack of sharp evidence for the expiration of the policy. First, many of the investment projects benefiting most from bonus depreciation—radio towers, farm buildings, electricity distribution systems, telephone communication systems, etc.—likely require substantial time-to-build and may have long lead times. In recognition of the time-to-build of complex pieces of equipment, the original tax bill permitted certain property to claim bonus depreciation as late as January 1, 2006.[18]

Second, projects that did not qualify for this extension needed to be installed by the end of 2004 to receive the bonus. Thus many firms had an incentive to frontload the projects to avoid missing the deadline. Many investment projects requiring more than one year lead time were effectively not subsidized in 2004.

Third, the increased small-business exemptions under Section 179 undoubtedly influence our results. The increased 179 exemption shares many of the features of bonus depreciation. The 179 exemption is equivalent to a 100 percent bonus depreciation on qualified investment up to the maximum deduction under 179.[19] Prior to 2002, businesses could expense \$24,000 of investment per year. The 2002 bill raised this ceiling temporarily to \$25,000. This exemption, like bonus depreciation, was set to expire at the end of 2004. The 2003 bill increased the ceiling further to \$100,000 and extended the expiration data to the end of 2005.[20] Thus, in our data, the average effective bonus rate exceeds the statutory rates of 30 or 50 percent that we assume in our structural

[17] A National Association of Business Economics (NABE) survey in January 2004 found that 62 percent of business economists expected the policy to be extended.

[18] To qualify for the extended expiration date, the property had to have a recovery period of at least 10 years, and either have a production period of at least two years or cost more than \$1 million, and have a production period of at least one year.

[19] Firms above the cutoff faced the 30 or 50 percent bonus rate. However, like many features of the U.S. tax code, the 179 exemption has a phase-out range above its exemption cutoff. Thus, firms that are just above the cutoff faced effective bonus rates between 100 and 30 or 50 percent.

[20] The 2004 *Working Families Tax Relief Act*, approved by Congress in September 2004, extend the \$100,000 Section 179 ceiling to the end of 2007. It also extended several provisions that were scheduled to sunset. The bonus depreciation allowance was not among the extensions. The extended provisions include the child tax credit, the 10 percent tax bracket, marriage penalty relief and AMT relief, all of which were set to expire under pre-existing law.

estimation. Moreover, because 179 was set to expire later, to the extent that it stimulates investment, it will obscure the expiration of the 50 percent bonus at the end of 2004.

In summary, the pattern of changes our theory predicts is clearly evident in the cross-sectional investment data. Likewise, our econometric model yields a high estimate for the elasticity of supply. On the other hand, complications in the timing of the expiration of the policy, the confounding differential expiration of the Section 179 expensing, and time-to-build of large projects make the time-series evidence less sharp.

5.5. Related Empirical Literature

We do not attempt to summarize the huge literature that uses tax changes to estimate investment models. Instead, we focus on a few papers that are closely related to our work.

Goolsbee [1998] presents evidence that increases in the Investment Tax Credit bids up prices without sharp increases in real investment. This finding contrasts with our results which show that investment spending reacted strongly to bonus depreciation, but do not show a clear price reaction. Although we do not know exactly what is responsible for the discrepancy, two important differences in the policies Goolsbee examines and the bonus depreciation analyzed here could play a role. First, bonus depreciation was explicitly temporary, while the ITC (the focus of Goolsbee's paper) was more persistent. On the one hand this suggests that investment spending should respond more but, on the other hand, it also means that prices should respond more. Second, while the ITC applied evenly to a broad class of equipment, bonus depreciation was concentrated on a narrow portion of total investment. Because the tax policy gave strong tax incentives to certain "quasi-structures" but not to business structures in general, there was substantial room for substitution across these industries. For example, bonus depreciation provides a substantial subsidy to farm structures. It is natural to think that firms that build other structures (that were not subsidized) could easily switch temporarily to construct farm structures while the policy was in effect.[21]

[21] It is possible that price data imperfectly reflect high frequency variation that would arise from temporary tax changes. If so, this measurement problem could be another source of the difference between our results and Goolsbee's, which were based on more persistent tax changes. Nevertheless, the predicted movements

Based on a difference-in-difference specification, Cohen and Cummins [2006] in a paper written after the first draft of this paper was circulated, conclude that bonus depreciation was largely ineffective. Some of the details of their analysis lead it to have little power to detect the effects of the bonus. First, they aggregate investment into two groups: five-year capital or less, and seven-year capital or more. The two groups function as a treatment group and a control group. Because of the relative abundance of five and seven-year capital in total investment, this aggregation implies that Cohen and Cummins are effectively comparing five-year and seven-year capital, neither of which gets much benefit from bonus depreciation (see Table 3, Panel B). Second, they date the onset of the policy in 2003:2 and assume that the expiration is in 2005:1. Our results show, however, that the policy was anticipated perhaps as early as 2001:4 and the expiration, for reasons discussed above, was not a sharp cutoff.

Knittel [2005a, 2005b] presents evidence based on IRS tax returns that many businesses—particularly small businesses—claimed neither bonus depreciation nor the 179 exemption to the fullest extent even though they had qualified investments. Although Knittel's finding presents a puzzle from the standpoint of basic economics, it does not invalidate the central arbitrage argument underlying our analysis. Suppose investment decisions were made by two groups of individuals: rational firms that react the way theory dictates, and irrational firms whose spending is exogenous and thus unresponsive to policy (perhaps because they do not understand the tax code and thus frequently file in a manner that is not to their advantage). This modification would change neither our main theoretical results nor our econometric approach nor the aggregate effects of the policy. In equilibrium, the rational investors are indifferent as to when they invest. Indeed, this near indifference is the heart of our empirical and theoretical results. Even if they are in the minority, because they effectively arbitrage predictable movements in the after-tax price, the behavior of the rational agents will cause the after-tax price to stay at its steady state level. As before, price fully reflects the subsidy and investment is determined by the supply curve.

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in quantities are so large relative to those of prices (see Figure 3) that our test should still reveal the effects of the policy in quantity data even if the price data used to construct them do not.

Finally, our estimates of the elasticity of investment supply are related to the literature on the estimation of investment adjustment costs. Early estimates, based on Brainard-Tobin's *Q* suggested implausibly high adjustment costs (see Hayashi [1982], Summers [1981], and Tobin [1981]). Estimates based on the firm's first-order condition typically lead to low to moderate adjustment costs (see Shapiro [1984] and Hall [2004]). Similarly, more recent estimates based on the *Q* theory that take into account timing, gestation lags, and measurement errors lead to more moderate adjustment costs (see Erickson and Whited [2000] and Millar [2005]). Our estimates of an elasticity of investment supply between 10 and 20 correspond to adjustment cost elasticities in the *Q* framework of between 1 and 2.[22] Hence, as with the more recent estimates, we find that adjustment costs are quite low.

VI. Aggregate Effects of the 2002 and 2003 Tax Laws

We now consider the possible aggregate effects of the tax laws. To do so, we use the estimates from Section V to calibrate the general equilibrium model and then we simulate the aggregate effects of the tax policy.

6.1 Calibration

We calibrate the model to match broad features of the U.S. economy and to match our estimates from the previous section. Our estimates of the elasticity of investment supply fall between 11 and 21. For our baseline calibration we take a value that is roughly in the midpoint of this range and set ξ equal to 15. The remaining parameters are set as follows. The annual discount factor (β) is 0.97, which gives a 3 percent annual real interest rate. The annual rate of inflation (π) is 3 percent. The Frisch labor supply elasticity (η) is 0.5 which is in line with recent estimates (see Farber [2003] and Kimball and Shapiro [2003]). We set σ, the elasticity of intertemporal substitution, to 0.2, which is roughly the average estimate in Hall [1988], Campbell and Mankiw [1989] and Barsky, *et al.* [1997]. To calibrate labor's share, we take the average value of total employee

[22] Recall that $\xi=(\gamma\delta)^{-1}$ where γ is the elasticity of adjustment costs in Hayashi's formulation (see footnote 1). For an average depreciation rate of 5 percent, ξ of 10 or 20 corresponds respectively to γ of 2 or 1.

compensation as a fraction of total GDP less proprietors' income over the post war period. This gives $1-\alpha = 0.62$. We set the share of government purchases in steady state to 0.2 which is roughly the average over 1990 to 2005. We calibrate the capital tax rates (τ^{π} and τ^{d}) to match the average marginal tax rates across income sources as detailed in the appendix. This gives $\tau^{\pi} = 0.22$ and $\tau^{d} = 0.30$. These calibrations account for differences in forms of ownership and for differences in financial structure. The baseline parameter values are summarized in Table 5. (The calibration of the labor tax rate τ^{N}, which is constant, has no influence on our results.)

We allow for ten different types of capital. Having this many types of capital allows us to capture the heterogeneity in depreciation schedules in the U.S. tax code. The economic rates of depreciation for each type of capital are based primarily on Fraumeni [1997].[23] The approximate MACRS depreciation rates ($\hat{\delta}^{m}$) are defined to be broadly consistent with IRS publication 946 and with Brazell and Mackie [2000]. The capital share parameters (γ_{m}) are set to match the relative investment shares from the U.S. National Income and Product Accounts. Investment shares are not constant over the post-war period. Since the policies we analyze are current, we choose γ_{m} to match the model's investment shares with their empirical averages from 1990-2002. Table 6 lists the capital types included in the model together with their economic and tax depreciation rates and shares of total investment. See the appendix for more details on our calibration.

In the simulations, the timing of the bonus depreciation allowance follows the timing of the enactment of the legislation and that all of the policy changes are unanticipated. A simulation with anticipations of the policy during the retroactive period would have similar aggregate effects, but with an onset two quarters earlier. The simulation also has a sharp cutoff at the expiration of the bonus. Adding time-to-build would move the effects of the bonus earlier.

6.2 The 2002 and 2003 Tax Laws: Baseline Simulation

Figure 5 shows the simulated reaction to the bonus depreciation allowances. The top two panels show the responses of GDP, total employment, aggregate investment and

[23] These rates are estimated using techniques established by Hulten and Wykoff [1981a, 1981b].

aggregate consumption. The lower panels show the response of investment for each type of capital.

Employment, output, and investment increase after each policy change. The biggest effects come after the 2003 law. In the quarter after *JGTRRA* passes, GDP is 0.18 percent above trend. Employment and aggregate investment are 0.19 and 1.80 percent above trend. Consumption decreases by 0.06 percent relative to trend. To put these figures in perspective, based on actual GDP in 2003 ($11 trillion) and total employment in 2003 (130 million workers), bonus depreciation increased GDP by roughly $17.4 billion and increased employment by roughly 191 thousand jobs (assuming the increase in employment is entirely at the extensive margin).

The modest effects of the policies are due to the fact that many types of investment goods are not substantially affected. Housing, and (most) business structures fail to qualify for bonus depreciation. Furthermore, most qualified investment is not substantially affected by the policy. Five-year property, vehicles and computer equipment for instance, get only small subsidies. For the U.S., the investments that are significantly affected account for at most 9 percent of total investment.

The simulated effects of the policy are more striking when one compares investment across types of capital (the bottom panels of the figure). At one extreme are farming structures,[24] rail structures, and electric power structures which increase by almost 40.0 percent after *JGTRRA*. Telephone structures and other power and utility structures increase by 30 percent. At the other extreme, residential investment and commercial structures both contract by roughly 6 percent.

Note that aggregate investment does not fall below steady state when the policy expires. First, there is an increase in investment in structures. (Industrial and residential structures have essentially the same path, so only the line for residential structures shows in the Figure 5.) During the period of the bonus, investment in capital that did not receive the bonus is depressed by the aggregate scarcity of resources. Second, though investment in qualified types falls below steady state, the reductions following the expiration of the bonus are smaller that the high rates of investment during 2002:2 to 2004:4. There are two reasons for the lack of an investment slump following the

[24] This category does not include single purpose agricultural structures.

expiration. First, while it is true that once the subsidy expires the stock of qualified capital is above steady state, the stock is not far above steady state. The capital goods that were affected most had very low depreciation rates and thus the stock is a slow moving variable even when investment is abnormally high. Second, to bring these capital stocks back to steady state, there is a gradual reduction in investment spread out over many periods in the future rather than a sharp reversal in investment rates.

6.3 The 2002 and 2003 Tax Laws: Alternative Parameter Values

Table 7 considers several alternatives to our baseline calibration. For each specification we document the change in GDP and total employment in 2003 predicted by the model. The different specifications are described in the table. Parameters not explicitly stated in the table are set at their baseline values.

As we decrease the elasticity of investment supply the aggregate effects decrease moderately. Reducing ξ to 10 implies that GDP in 2003 increases by 0.145 percent and employment in 2003 increases by 183 thousand jobs. Similarly, a higher elasticity magnifies the changes in GDP and employment modestly. As discussed above, our estimates are high relative to the literature on internal investment adjustment costs. In this case the increase in 2003 GDP is only 0.098 percent and the increase in employment is 132 thousand jobs.

Changing the tax structure of the model has strong effects on the outcome. For instance, the 2003 tax law also reduced dividend and capital gains taxes to 15 percent for most individuals. If we set $\tau^d = 0.15$ rather than 0.30 then the increase in GDP in 2003 is 0.207 percent and roughly 268 thousand jobs are created. Naturally, more elastic labor supply causes the economy to expand more. A higher intertemporal elasticity of substitution for consumption ($\sigma = 1$) implies that households are more willing to reduce consumption to finance investment. Thus, employment and production react less when σ is higher. Variations in the nominal interest rate change the value of the bonus depreciation allowance. When nominal interest rates are only 4 percent for instance, the increase in GDP is only 0.114 percent in 2003.

The effects of the policy are modest across all of these specifications. For the most part, the predicted increase in 2003 GDP lies between 0.10 and 0.20 percent of GDP and employment increases by roughly 100,000 to 200,000 jobs.

VII. CONCLUSION

Because the value of long-lived capital is dictated by long-run considerations, it is not sensitive to changes in the timing of purchase or installation. As a result, there are strong incentives to alter the timing of investment in response to temporary tax subsidies. These incentives are so strong that for a sufficiently temporary tax change, or a sufficiently long-lived capital good, the shadow price of new investment changes to fully reflect the tax subsidy regardless of the elasticity of investment supply. Observing that prices of such capital goods rise following explicitly temporary tax incentives does not imply that the supply of such goods is inelastic. Instead, the elasticity of supply can be inferred from quantity data alone. While prices do not reveal the elasticity of supply, price data can reveal the composition of internal versus external adjustment costs. If prices only partially reflect the subsidy then a significant fraction of the cost of investment is internal to the firm.

The high elasticity of intertemporal substitution implies a structural relationship between investment and changes in the cost of capital goods that holds under very general conditions. Because the relationship depends only on an arbitrage argument, unlike approaches based on *Q*-theory, we do not require strong assumptions on the form of the production function, returns to scale, or homogeneity of the adjustment cost function. Instead, our results simply require an upward sloping investment supply function and sufficiently temporary tax subsidies. The implied relationship also shows precisely how to control for changes in the aggregate scarcity of resources and therefore takes into account general equilibrium effects of the policy. For policy changes that have broad effects, the general equilibrium channel can substantially attenuate the impact of the policy on investment even with a high elasticity of supply (low adjustment costs).

The general results hold for only the specific circumstance of a sufficiently temporary change in the cost of purchasing capital goods. Calculations show that for long-lived durable capital goods, even changes in tax policy that last for several years can safely be modeled as temporary. Given the frequency of changes in tax policy, our analysis can be applied to many episodes.

The bonus depreciation allowance passed in 2002 and then increased in 2003 provides an opportunity to estimate the effective elasticity of investment supply and to test the theory. Only investment goods with a tax recovery period less than or equal to 20 years qualify for the bonus depreciation. The theory suggests that there should be a sharp difference in the response of investment spending between the 20-year investment goods and those with more than a 20-year recovery period. In addition, among the qualified investment goods, we should observe higher investment spending for goods with higher tax recovery periods. The data support both predictions. Bonus depreciation appears to have had a powerful effect on the composition of investment. Capital that benefited substantially from the policy, namely equipment with long tax lives, saw sharp increases in investment. In contrast, there is no evidence that market prices increased due to the policy.

Although the policy expired in 2005, it is not clear whether investment spending returned to normal as one would predict. This is likely due to the extension of bonus depreciation for certain properties and the increased Section 179 exemption (a tax incentive that shares many of the features of bonus depreciation).

Because the data indicate that qualified investment goods responded strongly to the tax policy, the estimated investment supply elasticities are quite high—roughly between 10 and 20. We use our estimates to assess the likely aggregate impacts of the policy. Because the policy was narrowly focused on a small subset of investment spending, we find that it had only modest effects on aggregate employment and output despite the stark effects on the composition of investment.

REFERENCES

Abel, Andrew B. 1982. "Dynamic Effects of Permanent and Temporary Tax Policies in a *q* Model of Investment." *Journal of Monetary Economics* 9, May, pp. 353-373.

Auerbach, Alan J., and Hines, James R. 1987. "Anticipated Tax Changes and the Timing of Investment." In *The Effects of Taxation on Capital Accumulation*, Martin Feldstein ed., Chicago: University of Chicago Press, pp. 163-196.

Barsky, Robert B., F. Thomas Juster, Miles S. Kimball and Matthew D. Shapiro. 1997. "Preference Parameters and Behavioral Heterogeneity: An Experimental Approach in the Health and Retirement Study." *Quarterly Journal of Economics* 112(2), pp. 537-579.

Brazell, David W., and Mackie, James B. 2000. "Depreciation Lives and Methods: Current Issues in the U.S. Capital Cost Recovery System." *National Tax Journal* 53(3), pp. 531-562.

Campbell, John and Mankiw, N. Gregory. 1989. "Consumption, Income and Interest Rates: Reinterpreting the Time Series Evidence." *NBER Macroeconomics Annual* 4: 185-216.

Cohen, Darrel S. and Cummins, Jason. 2006. "A Retrospective Evaluation of the Effects of Temporary Partial Expensing." Federal Reserve Board, Finance and Economics Discussion Series working paper No. 2006-19, April.

Cohen, Darrel S., Hansen, Dorthe-Pernille, and Hassett, Kevin A. 2002. "The Effects of Temporary Partial Expensing on Investment Incentives in the United States." *National Tax Journal*, September, 55(3), pp. 457-466.

Erickson, Timothy and Whited, Toni M. 2000. "Measurement Error and the Relationship between Investment and *q*." *Journal of Political Economy* 108(5), pp. 1027 – 1057.

Farber, Henry S. 2003. "Is Tomorrow Another Day? The Labor Supply of New York City Cab Drivers." Princeton University, Working Paper No. 473.

Fraumeni, Barbara M. 1997. "The Measurement of Depreciation in the U.S. National Income and Product Accounts." *Survey of Current Business*, July, pp. 7-23.

Goolsbee, Austan. 1998. "Investment Tax Incentives, Prices, and the Supply of Capital Goods." *Quarterly Journal of Economics* 113(1), February, pp. 121-148.

Hall, Robert E. 1988. "Intertemporal Substitution in Consumption." *Journal of Political Economy* 96(2), April, pp. 339-357.

Hall, Robert E. 2004. "Measuring Factor Adjustment Costs." *Quarterly Journal of Economics*, August, pp. 899-927.

Hall, Robert E. and Jorgenson, Dale W. 1967. "Tax Policy and Investment Behavior." *American Economic Review* 57(3), June, pp. 391-414.

Hayashi, Fumio. 1982. "Tobin's Marginal *q* and Average *q*: A Neoclassical Interpretation." *Econometrica* 50, January, pp. 213-224.

House, Christopher L. and Shapiro, Matthew D. 2006. "Phased-In Tax Cuts and Economic Activity." Forthcoming in the *American Economic Review*, also available as *NBER* working paper No. 9832.

Hulten, Charles R., and Wykoff Frank C. 1981a. "The Estimation of Economic Depreciation Using Vintage Asset Prices: An Application of the Box-Cox Power Transformation." *Journal of Econometrics* 15(3), April, 367-396.

Hulten, Charles R., and Wykoff Frank C. 1981b. "The Measurement of Economic Depreciation," in Charles R. Hulten eds. *Depreciation, Inflation, and the Taxation of Income from Capital.* Washington, D.C: Urban Institute Press, 81-125.

Internal Revenue Service. 2003 *How to Depreciate Property*. Department of the Treasury, IRS Publication 946.

Joint Committee on Taxation, *Description of the "Economic Security and Recovery Act Of 2001*" (JCX-69-01), October 11, 2001

Joint Committee on Taxation, *Summary of P. L. 107-147, the "Job Creation and Worker Assistance Act of 2002"* (JCX-22-02), March 22, 2002.

Jorgenson, Dale W. 1963. "Capital Theory and Investment Behavior." *American Economic Review* 53(2), May, pp. 247-259.

Jorgenson, Dale W. and Yun, Kun-Young. *Tax Reform and the Cost of Capital*. Oxford University Press, 1991.

Kimball, Miles and Matthew D. Shapiro. 2003. "Labor Supply: Are Income and Substitution Effects Both Large or Both Small?" Unpublished paper, University of Michigan.

Knittel, Matthew. 2005a. "Taxpayer Response to Partial Expensing: Do Investment Incentives Work as Intended?" Department of Treasury Working Paper.

Knittel, Matthew. 2005b. "Small Business Utilization of Accelerated Tax Depreciation: Section 179 Expensing and Bonus Depreciation." Department of Treasury Working Paper.

Lucas, Robert E. 1976. "Econometric Policy Evaluation: A Critique." *Carnegie-Rochester Conference Series on Public Policy* (1) pp. 19-46.

Millar, Jonathan N. 2005. "Gestation Lags and the Relationship Between Investment and Q in Regressions." Finance and Economics Discussion Series No. 2005-28. Board of Governors of the Federal Reserve System.

Mussa, Michael L. 1977. "External and Internal Adjustment Costs and the Theory of Aggregate and Firm Investment." *Economica* 44, May pp. 163-178.

NABE Industry Survey, January 2004. National Association for Business Economics, Washington, D.C.

Shapiro, Matthew D. 1986. "The Dynamic Demand for Capital and Labor," *Quarterly Journal of Economics* 101, August, pp. 513-542.

Summers, Lawrence H. 1981. "Taxation and Corporate Investment: a *q*-Theory Approach." *Brookings Papers on Economic Activity* 1981(1), pp 67-127.

Summers, Lawrence H. 1985. "Requiem for the Investment Equation." Unpublished mimeo, Harvard University.

Tobin, James. 1981. "Discussion of 'Taxation and Corporate Investment: a *q*-Theory Approach.'" *Brookings Papers on Economic Activity*. 1981(1), pp 132-139.

APPENDICES

A.1. The Steady State

The model has a non-stochastic steady state equilibrium associated with constant tax rates and a constant rate of government spending. Here we briefly outline how this steady state is calculated.

In steady state $K_t^m = K^m$, $I^m = \delta^m K^m \ \forall m$. As a matter of convenience, we assume that the average cost of investment (like the marginal cost of investment) is 1 in steady state. This requires placing assumptions on the production functions which generate the supply functions $\varphi^m(I_t^m)$.[25] Thus $\varphi_t^m = 1$ for all *m*. Equations (8) then imply $q^m = C^{-\frac{1}{\sigma}}[1-\zeta^m]$. We calculate the steady state subsidy ζ^m according to equation (21) in the text with no bonus depreciation rate. The approximate tax depreciation rates $\hat{\delta}^m$ are the ratio of the declining balance rate for the type of capital in question divided by the recovery period (e.g., for automobiles, the declining balance rate is 200 percent, and the recovery period is 5 years so $\hat{\delta}^m$ is 40 percent).

The real and nominal interest rates are $1+r=\beta^{-1}$ and $1+i=(1+r)(1+\pi)$. The Euler equations (7) give the real rental prices for each type of capital

$$R^m = \frac{(r+\delta^m)(1-\zeta^m)}{(1-\tau^\pi)(1-\tau^d)}.$$

With R^m, we can express the steady state capital stocks K^m in terms of one reference capital stock. We take *m* = 1 as the reference capital stock. Then, (10) implies that that any other capital stock is given by

$$K^m = \left[\frac{R_t^1}{R_t^m}\frac{\gamma_m}{\gamma_1}\right]K^1 = \psi_{m,1}\cdot K^1$$

with $\psi_{m,1} \equiv \frac{R_t^1}{R_t^m}\frac{\gamma_m}{\gamma_1}$. Together with the production function (9), total output is

$$Y = A\cdot\Xi^\alpha\left(K^1\right)^\alpha\left(N\right)^{1-\alpha}.$$

with $\Xi = \prod_{m=1}^{M}\left(\psi_{m,1}\right)^{\gamma_m}$. Equation (10) pins down the equilibrium capital to labor ratios and, with equation (11), the output to labor ratio. The pre-tax real wage is then,

[25] The corresponding cost function is

$$\Phi^m\left(I_t^m\right) = \bar{I}^m\left\{\frac{\xi}{1+\xi}\left(\frac{I_t^m}{\bar{I}^m}\right)^{\frac{1+\xi}{\xi}} + \frac{1}{1+\xi}\right\},$$

where $\xi > 0$. This function can be inverted to get the production function $I^m(\Phi_t^m)$. Note that this formulation includes a flow fixed cost of production which is necessary to allow for an increasing marginal cost but for equal marginal and average costs in the steady state. We assume that there are many firms (measure 1) that produce investment goods each with the same cost/production function. The firms behave competitively but there is no entry.

$$W = (1-\alpha)\frac{Y}{N}.$$

Let g be the ratio of government spending to GDP and let $\Gamma \equiv \frac{Y(1-g)}{N} - \sum_m \delta^m \frac{K^m}{N}$.

Goods market clearing then implies $C = N \cdot \Psi$ which with (5) gives steady state employment as

$$N = \left[\frac{W}{\phi}(1-\tau^N)\Gamma^{-\frac{1}{\sigma}}\right]^{\frac{1}{\frac{1}{\eta}+\frac{1}{\sigma}}}.$$

A.2. Notes on Calibration

We set γ_m to match the relative steady state levels of investment with the corresponding investment rates in the data. We begin with the real rental prices R^m and compare type 1 capital with the other types. We can write the relative rental prices as

$$\frac{R^1}{R^m} = \frac{\gamma_1}{\gamma_m}\frac{K^m}{K^1} = \frac{\gamma_1}{\gamma_m}\frac{I^m}{I^1}\frac{\delta^1}{\delta^m},$$

which implies $\gamma_m = \gamma_1 \cdot \mu_{m,1}$, where $\mu_{m,1} \equiv \frac{R^m}{R^1}\frac{I^m}{I^1}\frac{\delta^1}{\delta^m}$. Since $\sum_{m=1}^{M}\gamma_m = 1$, we set

$$\gamma_1 = \left[\sum_{m=1}^{M}\mu_{m,1}\right]^{-1}.$$

We use NIPA data to calibrate the investment ratios I^m / I^1; we use depreciation figures from Fraumeni [1997] to calibrate the depreciation ratios δ^1/δ^m.

To calibrate τ^π and τ^d, we assume that, for all types of capital (other than residential capital), payments, depreciation, transfers, and indirect business taxes are split between proprietorships and corporations. The fraction of the corporate sector is calibrated from NIPA data by taking the sum of corporate profits and net interest and dividing by the sum of corporate profits, net interest and proprietors' capital income as defined in Section 5.3. For 1990-2002, the ratio of corporate capital income to total capital income is $F^{corp} = 0.85$. Proprietors deduct depreciation directly from their personal income. We assume that marginal tax rates for proprietors are 0.30, which is roughly the average tax rate for upper income individuals. This income is only taxed once so, for proprietorships, $\tau^\pi = 0.30$ and $\tau^d = 0$.

We treat the corporate sector as financed partially with debt and partially with equity. We calculate the share of equity finance as the ratio of corporate profits (before tax) to the sum of corporate profits plus net interest income. For 1990-2002, this fraction is $f^{eq} = 0.60$. Equity is taxed first as corporate profits and then as dividend income. The statutory tax rate on corporate profits is roughly 0.35. Because dividend income is highly skewed, we assume that all dividends are paid to people at the top income tax bracket. Thus, for equity, $\tau^\pi = 0.35$ and $\tau^d = 0.35$. Debt financing avoids the corporate tax but is subject to the income tax rate. We treat debt finance as $\tau^{\pi}=0$ and $\tau^{d}=0.35$. The overall tax rates are:

$$\tau^{\pi}=\left[1-F^{corp}\right]\cdot 0.3+F^{corp}\cdot\left\{f^{eq}\cdot 0.35+\left(1-f^{eq}\right)\cdot 0\right\}=0.2235,$$

$$\tau^{d}=\left[1-F^{corp}\right]\cdot 0+F^{corp}\cdot\left\{f^{eq}\cdot 0.35+\left(1-f^{eq}\right)\cdot 0.35\right\}=0.2975.$$

A.3. Data

The data on investment by type are taken from the Underlying Detail Tables for the BEA National Economics Accounts. Specifically, tables 5.4.4AU, 5.4.4BU, 5.4.5AU, 5.4.5BU, 5.4.6AU, 5.4.6BU, 5.5.4U, 5.5.5U, and 5.5.6U. For equipment, the investment categories used are on lines: 5-11, 13, 15-20, 22, 25-28, 34, 35, 37-40; for structures, the categories used are on lines: 4, 7, 14, 17-19, 21, 22, 24, 25, 27, 28, and 34. The category for railroad structures (see Table 6) disappears after 1997. After 1997, railroad structures are included in land, which the BEA describes as "primarily consisting of railroads". Data on the investment tax credit by asset type are from Dale Jorgenson. These data are constructed using the methods described in Jorgenson and Yun [1991]. Data for real and nominal GDP, the Federal Funds Rate, the 10-year Treasury rate, the CPI and the GDP Deflator are taken from the FRED database at the St. Louis Federal Reserve Bank.

A.4. The Recovery of Depreciation under the U.S. Tax System

This section provides additional details about the *Modified Accelerated Cost Recovery System* or MACRS. For more information the reader should consult IRS Publication 946 *How to Depreciate Property*.

Businesses deduct the costs of most capital investments from taxable income in the years following the initial investment. Almost all tangible assets can be depreciated provided that their primary use is in production.[26] In general, deductions begin the year the property is placed in service. Firms may depreciate the cost of the asset as well as any installation fees, freight charges, and sales tax. Thus, the bonus depreciation allowance applies to external and internal costs symmetrically.

MACRS has three depreciation methods: 200 percent and 150 percent declining balance methods, and straight-line depreciation. The declining balance methods are combinations of geometric depreciation and straight-line depreciation. In the early phase of the recovery period, declining balance methods use fixed geometric depreciation rates. If the recovery period is *R*, the 200 percent annual declining balance rate is 200 percent/*R*; the 150 percent declining balance rate is 150 percent/*R*. Only non-farm property with recovery periods of 10 years or less may use the 200 percent declining balance method. All farm property and all 15 and 20-year property uses the 150 percent declining balance rate. Non-residential real property (business structures) and rental property use the straight-line method.

[26] Computer software, patents and other intangible assets are also eligible for depreciation. If the asset is only partially devoted to business activity then only a fraction of the property is depreciable. Appendix A.4 provides a more detailed discussion of MACRS. For more details on depreciation in the U.S. tax system see IRS Publication 946.

These rates, together with the original cost of the capital, dictate the tax deductions each year until a straight-line depreciation rate (over the remaining part of the recovery period) exceeds the declining balance rate (in continuous time, the switch to straight-line depreciation would occur halfway through the assets recovery period).

Because depreciation deductions are made at discrete points in time, MACRS often treats property as though it was acquired and placed in service in the middle of the year. This is called a *half-year* convention.[27] Firms deduct half of a year's depreciation in the year the property was purchased. Thus, even though five-year properties have a 40 percent annual MACRS depreciation rate, the firm only deducts 20 percent in the first year (a consequence of half-year conventions is that property with a recovery period of R is actually recovered over a period of R+1 years with the first and last years accounting for half of a year). Table A.1 gives the exact schedule of MACRS depreciation deductions for various recovery periods assuming a half-year convention. In the table, year 1 is the year of the purchase.

A.5 Estimators

This appendix briefly discusses the OLS and WLS estimators used in Section VI. Write $\hat{B}$ as the vector of parameter estimates, Y as the vector of left-hand-side variables and X as the matrix of right hand side variables in (26) and (27). Then, for $j = I$, p and for weighting matrix W

$$\hat{B}_j = \left(X_j{}'W_j^{-1}X_j\right)^{-1} X_j{}'W_j^{-1}Y_j, \tag{31}$$

$$Var\left(\hat{B}_j\right) = \hat{\sigma}_j^2 \left(X_j{}'W_j^{-1}X_j\right)^{-1} X_j{}'W_j^{-1}\hat{\Omega}_j W_j^{-1} X_j \left(X_j{}'W_j^{-1}X_j\right)^{-1}, \tag{32}$$

where

$$\hat{\sigma}_j^2 = \frac{\sum_{m=1}^{37}\sum_{h=1}^{20}\left(e_j^{h,m}\right)^2}{\text{trace}\left(\hat{\Omega}_j - X_j\left(X_j{}'W_j^{-1}X_j\right)^{-1} X_j{}'W_j^{-1}\hat{\Omega}_j\right)} \tag{33}$$

and $\hat{\Omega}_I = \hat{R}_I \otimes \hat{\Sigma}_I$ and $\hat{\Omega}_p = \hat{R}_p \otimes \hat{\Sigma}_p$. The OLS estimator corresponds to $W_j = I$ and WLS corresponds to $W_j = \text{diag}(\hat{\Omega}_j)$ for $j = I, p$.

[27] MACRS sometimes requires businesses to use mid-quarter or mid-month conventions.

TABLE 1: RESPONSE TO A TEMPORARY INVESTMENT SUBSIDY

Duration	Depreciation Rate	Shadow Price (φ)						
		$\xi = 0$	$\xi = 0.5$	$\xi = 1$	$\xi = 5$	$\xi = 10$	$\xi = 15$	$\xi = 20$
6 months	δ = .001	1.000	1.000	1.000	0.999	0.998	0.997	0.996
	δ = .01	1.000	0.999	0.998	0.992	0.986	0.982	0.978
	δ = .02	1.000	0.998	0.996	0.986	0.976	0.969	0.963
	δ = .05	1.000	0.996	0.992	0.970	0.951	0.936	0.923
	δ = .10	1.000	0.992	0.985	0.945	0.911	0.885	0.864
	δ = .25	1.000	0.982	0.965	0.877	0.807	0.755	0.714
1 year	δ = .001	1.000	1.000	0.999	0.997	0.995	0.993	0.991
	δ = .01	1.000	0.998	0.996	0.983	0.972	0.964	0.956
	δ = .02	1.000	0.996	0.993	0.972	0.954	0.940	0.928
	δ = .05	1.000	0.992	0.984	0.941	0.906	0.878	0.855
	δ = .10	1.000	0.985	0.971	0.896	0.835	0.790	0.753
	δ = .25	1.000	0.966	0.936	0.784	0.673	0.597	0.539
2 years	δ = .001	1.000	0.999	0.999	0.995	0.990	0.986	0.983
	δ = .01	1.000	0.996	0.992	0.967	0.946	0.930	0.915
	δ = .02	1.000	0.992	0.985	0.946	0.912	0.886	0.864
	δ = .05	1.000	0.984	0.969	0.890	0.826	0.779	0.740
	δ = .10	1.000	0.971	0.946	0.814	0.715	0.645	0.591
	δ = .25	1.000	0.941	0.891	0.659	0.515	0.428	0.368
3 years	δ = .001	1.000	0.999	0.998	0.992	0.985	0.980	0.975
	δ = .01	1.000	0.993	0.988	0.952	0.922	0.898	0.878
	δ = .02	1.000	0.989	0.979	0.921	0.873	0.837	0.807
	δ = .05	1.000	0.976	0.956	0.845	0.760	0.698	0.649
	δ = .10	1.000	0.959	0.925	0.749	0.626	0.545	0.485
	δ = .25	1.000	0.922	0.860	0.587	0.439	0.357	0.304
Permanent	δ = .001	1.000	0.986	0.972	0.884	0.806	0.749	0.704
	δ = .01	1.000	0.929	0.872	0.637	0.513	0.443	0.396
	δ = .02	1.000	0.908	0.839	0.578	0.453	0.387	0.343
	δ = .05	1.000	0.888	0.808	0.528	0.405	0.341	0.300
	δ = .10	1.000	0.879	0.794	0.506	0.384	0.322	0.282
	δ = .25	1.000	0.872	0.783	0.489	0.367	0.306	0.267

Note: The table shows the equilibrium change in the shadow price of capital goods φ in response to an investment subsidy of one percent ($\zeta = .01$). For the numerical calculations, the production function is Ak_t^{α}, $r = 0.02$, and $\alpha = 0.35$. Investment supply is given by equation (2).

TABLE 2: RECOVERY PERIODS AND DEPRECATION METHODS BY TYPE OF CAPITAL

Type of Capital	Recovery Period (R)	Tax Depreciation Rate (Method)
Tractor units for over-the-road use, horses over 12 years old or racehorses with over 2 years in service	3 years	66.7% (200% DB)
Computers & office equipment; light vehicles, buses and trucks	5 years	40.0% (200% DB)
Miscellaneous equipment,[1] office furniture, agricultural equipment[2]	7 years	28.6% (200% DB) & 21.4% (150% DB)
Water transportation equipment (vessels and barges), single purpose agricultural structures[2]	10 years	20.0% (200% DB) & 15.0% (150% DB)
Radio towers; cable lines; pipelines; electricity generation and distribution systems, "land improvements" e.g. sidewalks, roads, canals, drainage systems, sewers, docks, bridges; engines and turbines.	15 years	10.0% (150% DB)
Farm buildings (other than single purpose structures); railroad structures, telephone communications, electric utilities, water utilities structures including dams, and canals	20 years	7.5% (150% DB)
Non-residential real property (office buildings, storehouses, warehouses, etc)	39 years[3]	2.6% (SL)

Note: DB is "Declining Balance;" SL is "Straight-Line." Source: IRS Publication 946.

[1] Property that is not explicitly catalogued under the MACRS system is given a seven-year recovery period.
[2] All farm property uses the 150% declining balance method.
[3] Property placed in service prior to May 13, 1993 has a 31.5 year recovery period.

TABLE 3. PRESENT VALUE OF DEPRECIATION ALLOWANCES (z)

A. z with and without the 30% and 50% bonus depreciation

	Nominal rate = .03			Nominal rate = .05			Nominal rate = .07		
Recovery period	z	z +30%	z +50%	z	z +30%	z +50%	z	z +30%	z +50%
3-years	0.972	0.981	0.986	0.955	0.968	0.977	0.939	0.957	0.969
5-years	0.949	0.964	0.975	0.918	0.943	0.959	0.890	0.923	0.945
7-years	0.927	0.949	0.964	0.884	0.919	0.942	0.846	0.892	0.923
7-years (150DB)	0.914	0.939	0.957	0.863	0.904	0.932	0.818	0.872	0.909
10-years	0.896	0.927	0.948	0.837	0.886	0.919	0.786	0.850	0.893
10-years (150DB)	0.878	0.915	0.939	0.811	0.868	0.905	0.752	0.826	0.876
15-years	0.824	0.877	0.912	0.733	0.813	0.867	0.659	0.761	0.829
20-years	0.775	0.842	0.887	0.667	0.767	0.833	0.582	0.708	0.791

B. Tax Subsidy due to the Bonus Depreciation Allowance, Percent

	Nominal rate = .03		Nominal rate = .05		Nominal rate = .07	
Recovery period	30% Bonus	50% Bonus	30% Bonus	50% Bonus	30% Bonus	50% Bonus
3-years	0.44	0.74	0.72	1.20	0.97	1.63
5-years	0.81	1.35	1.28	2.15	1.71	2.88
7-years	1.15	1.92	1.79	3.02	2.36	3.99
7-years (150DB)	1.35	2.27	2.10	3.55	2.75	4.68
10-years	1.62	2.73	2.48	4.20	3.20	5.45
10-years (150DB)	1.88	3.17	2.85	4.85	3.67	6.26
15-years	2.66	4.52	3.91	6.70	4.89	8.42
20-years	3.36	5.72	4.78	8.24	5.83	10.11

Source: Authors' calculations based on statutory MACRS recovery schedules and 0.35 corporate tax rate.

TABLE 4: STRUCTURAL PARAMETER ESTIMATES

PANEL A: Investment Equation (26)

Row	Forecast Equation	Structural Equation	ξ WLS	ξ OLS	ξ/σ WLS	ξ/σ OLS
1	Baseline	Baseline	11.64 (2.55)	10.30 (3.60)	15.42 (2.44)	11.03 (5.08)
2	Time trend only	Baseline	10.87 (5.48)	12.48 (8.58)	14.89 (5.05)	15.84 (8.16)
3	Baseline	Time-varying *MU*(*C*)	21.84 (4.00)	16.81 (4.73)		
4	Time trend only	Time-varying *MU*(*C*)	22.21 (8.52)	20.52 (11.92)		

PANEL B: Price Equation (27)

Row	Forecast Equation	Structural Equation	$\beta_{p,1}$ WLS	$\beta_{p,1}$ OLS	$1/\sigma$ WLS	$1/\sigma$ OLS
1	Baseline	Baseline	-2.06 (1.50)	-1.47 (1.84)	0.21 (1.69)	0.69 (2.04)
2	Time trend only	Baseline	-1.39 (1.33)	-0.25 (2.15)	-0.03 (1.28)	0.69 (1.76)
3	Baseline	Time-varying *MU*(*C*)	-2.62 (2.16)	-1.68 (2.67)		
4	Time trend only	Time-varying *MU*(*C*)	-1.96 (1.68)	-0.32 (2.98)		

NOTES: The baseline forecast equation specification (rows 1 and 3) includes a constant, trend, and two lags of real GDP, real corporate profits, type-specific real investment, type-specific real relative prices and type-specific ITC. The trend only forecast equation specification (rows 2 and 4) includes only a constant and trend. The baseline structural specification (rows 1 and 2) uses HP-filtered consumption to measure aggregate marginal utility. The time-varying *MU(C)* specification (rows 3 and 4) uses time dummies. Estimates are by ordinary least squares (OLS) or weighted least squares (WLS). Standard errors in parentheses are corrected for time-series and cross-sectional dependence. See text and Appendix A.5 for details.

TABLE 5. BASELINE PARAMETERS FOR SIMULATIONS

Parameter	Baseline Value
Discount factor, annual rate (β)	0.97
Capital share (α)	0.38
Labor supply elasticity (η)	0.50
Elasticity of intertemporal substitution of consumption (σ)	0.20
Average inflation rate (π)	0.03
Investment supply elasticity (ξ)	15.00
Share of government spending in GDP (g)	0.20
Tax rate on capital earnings (τ^{π})	0.22
Tax rate on earnings distribution (τ^{d})	0.30

TABLE 6. CAPITAL TYPES USED FOR SIMULATION.

m	Type of Capital	Economic Depreciation δ^m	Tax Depreciation $\hat{\delta}^m$	Fraction of Investment (percent)
1	Construction equipment and tractors	0.17	0.40	1.38
2	Vehicles; office and computing equipment	0.30	0.40	28.49
3	Agricultural equipment	0.097	0.21	1.16
4	General equipment (incl. rail, furniture, aircraft, instruments, mining and oil, and household equipment)	0.100	0.29	21.66
5	Engines and turbines	0.079	0.10	0.40
6	Industrial buildings (incl. religious, education buildings, and hospitals)	0.03	0.03	11.60
7	Farm structures; rail; and electric power structures	0.025	0.08	2.02
8	Telephone, telegraph and misc. power and utility structures	0.04	0.10	1.62
9	Mining, shafts and wells	0.056	0.20	1.73
10	Residential and other structures	0.02	--	28.46

Note: Authors' calculations based on MACRS recovery schedules. For the calibration, these farm buildings do not include single purpose agricultural structures. Single purpose agricultural structures have a 10-year recovery period and are depreciated with a 150% DB method under MACRS. Farm structures other than single purpose structures are 20-year property (150% DB). In the data, farm structures are aggregated into one category. The last column gives fraction of investment since 1990 accounted for by the type. These types account for 98.5 of total investment. Excluded categories are water vessels, and lodging, recreation and amusement structures.

TABLE 7. SIMULATED EFFECTS OF A 50 PERCENT BONUS DEPRECIATION ALLOWANCE: ALTERNATIVE PARAMETERS

Parameters	GDP		Employment	
	Change from Trend (percent)	Change (billions of dollars)	Change from Trend (percent)	Number (1000s)
Baseline	0.158	17.4	0.147	191
Low Investment Elasticity, $\xi = 10$	0.145	16.0	0.141	183
"Adjustment Costs" $\xi = 3$	0.098	10.8	0.101	132
Low distribution tax, $\tau^d = 0.15$	0.207	22.7	0.206	268
High profit tax, $\tau^\pi = 0.35$	0.246	27.0	0.224	292
High Labor Supply Elasticity, $\eta = 1$	0.215	23.6	0.226	294
Log preferences (High IES), $\sigma = 1$	0.167	18.3	0.131	170
Low inflation, $\pi = 1$	0.114	12.5	0.108	140

Note: This table shows the results of simulating the effect of the 50% bonus depreciation provisions on 2003 GDP and employment. Parameters other than those specified in the table are set at their baseline values in Table 5.

TABLE A.1: MACRS RECOVERY SCHEDULES BY RECOVERY PERIOD, PERCENT PER YEAR

Year	3-year	5-year	7-year	10-year	15-year	20-year	27½-year	39-year
1	33.33	20.00	14.29	10.00	5.00	3.750	1.970	1.391
2	44.45	32.00	24.49	18.00	9.50	7.219	3.636	2.564
3	14.81	19.20	17.49	14.40	8.55	6.677	3.636	2.564
4	7.41	11.52	12.49	11.52	7.70	6.177	3.636	2.564
5		11.52	8.93	9.22	6.93	5.713	3.636	2.564
6		5.76	8.92	7.37	6.23	5.285	3.636	2.564
7			8.93	6.55	5.90	4.888	3.636	2.564
8			4.46	6.55	5.90	4.522	3.636	2.564
9				6.56	5.91	4.462	3.636	2.564
10				6.55	5.90	4.461	3.636	2.564
11				3.28	5.91	4.462	3.636	2.564
12					5.90	4.461	3.636	2.564
13					5.91	4.462	3.636	2.564
14					5.90	4.461	3.636	2.564
15					5.91	4.462	3.636	2.564
16					2.95	4.461	3.636	2.564
17						4.462	3.636	2.564
18						4.461	3.636	2.564
19						4.462	3.636	2.564
20						4.461	3.636	2.564
21						2.231	3.636	2.564
22-27							3.636	2.564
28							3.485	2.564
29-39								2.564
40								1.177

Notes: 15 and 20-year property are recovered with a 150% declining balance method. The 27.5 and 39-year property classes are recovered with a straight-line method with a half-year dating convention. Source: IRS Publication 946, *How to Depreciate Property*.

TABLE A.2. ECONOMIC AND MACRS DEPRECIATION BY DETAILED TYPE OF CAPITAL

Type of Capital	Economic Depreciation Rate δ^m	Recovery Period	Depreciation Method	Tax Depreciation Rate $\hat{\delta}^m$
Computers and peripheral equipment	0.300	5	200	0.400
Software	0.300	5	200	0.400
Communication equipment	0.300	5	200	0.400
Medical equipment and instruments	0.135	7	200	0.286
Nonmedical instruments	0.135	7	200	0.286
Photocopy and related equipment	0.180	5	200	0.400
Office and accounting equipment	0.150	5	200	0.400
Fabricated metal products	0.092	7	200	0.286
Internal combustion engines	0.210	15	150	0.100
Metalworking machinery	0.122	7	200	0.286
Special industry machinery	0.103	7	200	0.286
General industrial equipment	0.107	7	200	0.286
Electrical transmission and distribution, industrial apparatus	0.050	7	200	0.286
Trucks, buses, and truck trailers	0.190	5	200	0.400
Autos	0.165	5	200	0.400
Aircraft	0.110	7	200	0.286
Ships and boats	0.060	10	200	0.200
Railroad equipment	0.060	7	200	0.286
Farm tractors	0.145	5	150	0.300
Other agricultural machinery	0.118	7	150	0.214
Construction tractors	0.163	5	200	0.400
Other construction machinery	0.155	5	200	0.400
Mining and oilfield machinery	0.150	7	200	0.286
Service industry machinery	0.165	7	200	0.286
Commercial, including office buildings	0.025	39	SL	0.026
Hospitals and special care structures	0.019	39	SL	0.026
Manufacturing structures	0.031	39	SL	0.026
Electric structures	0.021	20	150	0.075
Other power structures	0.024	15	150	0.100
Communication structures	0.024	15	150	0.100
Petroleum and natural gas	0.075	5	SL	0.200
Mining	0.045	5	SL	0.200
Religious structures	0.019	39	SL	0.026
Educational structures	0.019	39	SL	0.026
Railroad structures	0.018	20	150	0.075
Farm structures	0.024	20	150	0.075

Note: The table lists the types of investment goods in the data set used in our empirical specification. All rates are annual. For the depreciation method, 200 indicates the 200 percent double declining balance method; 150 indicates the 150 percent declining balance method; and SL is straight line depreciation. The tax depreciation rate is the declining balance rate divided by the recovery period (for SL it is simply the inverse of the recovery period).

FIGURE 1: PRICE REACTIONS TO TEMPORARY INVESTMENT SUBSIDIES.

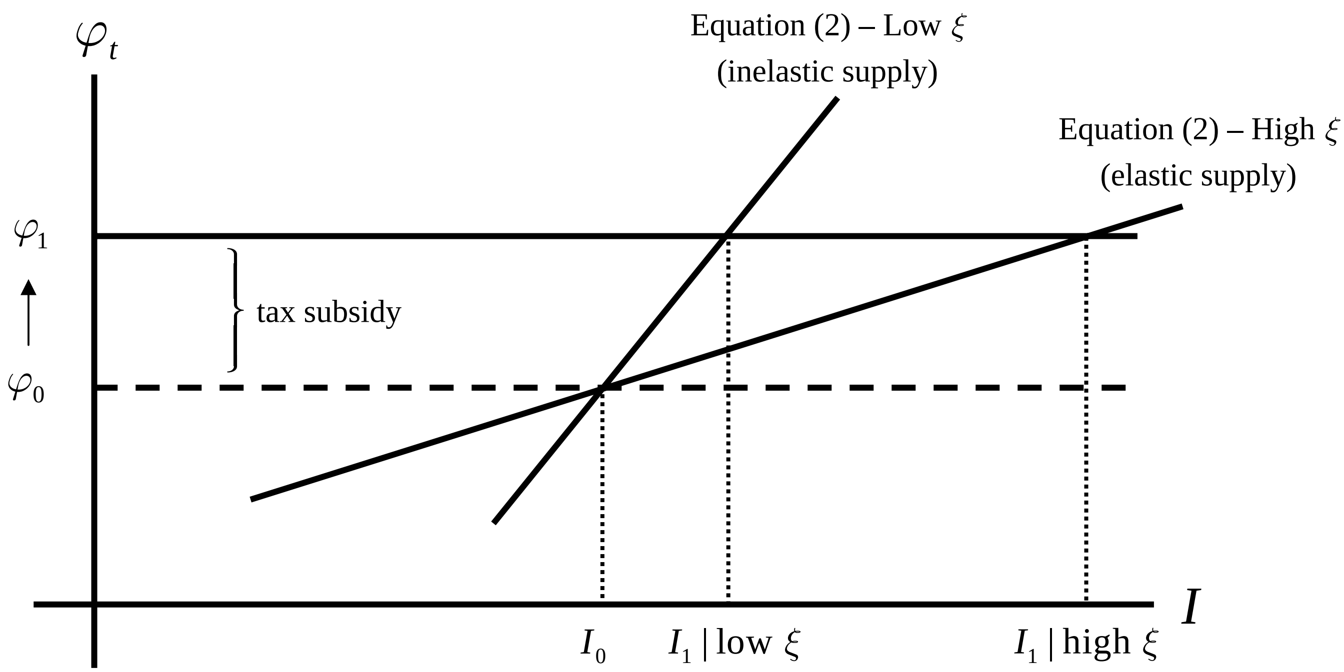
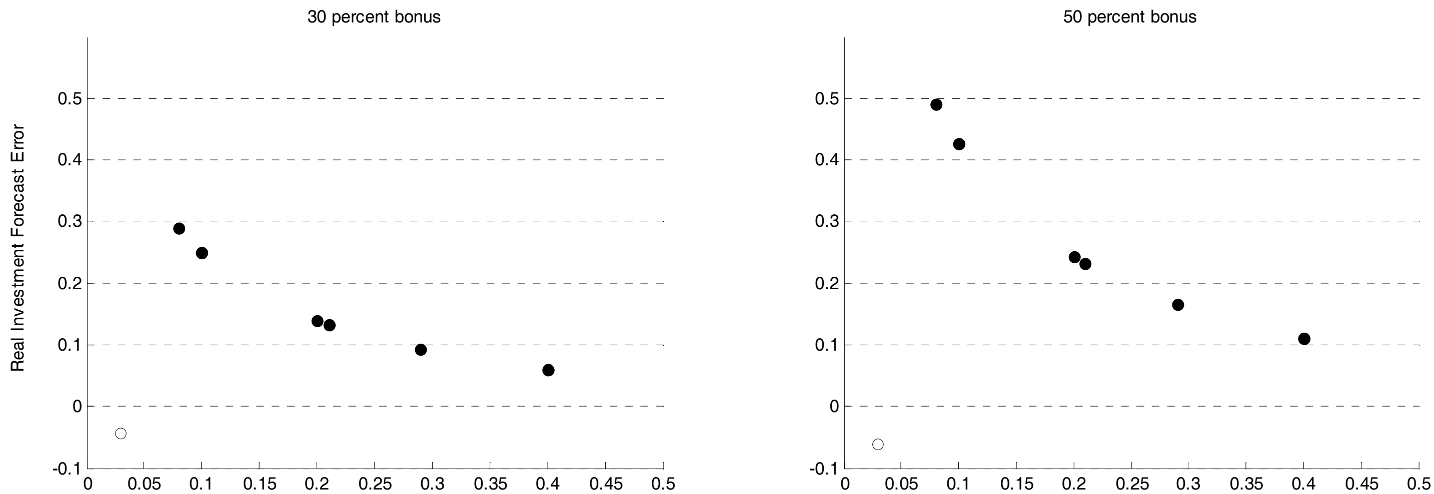
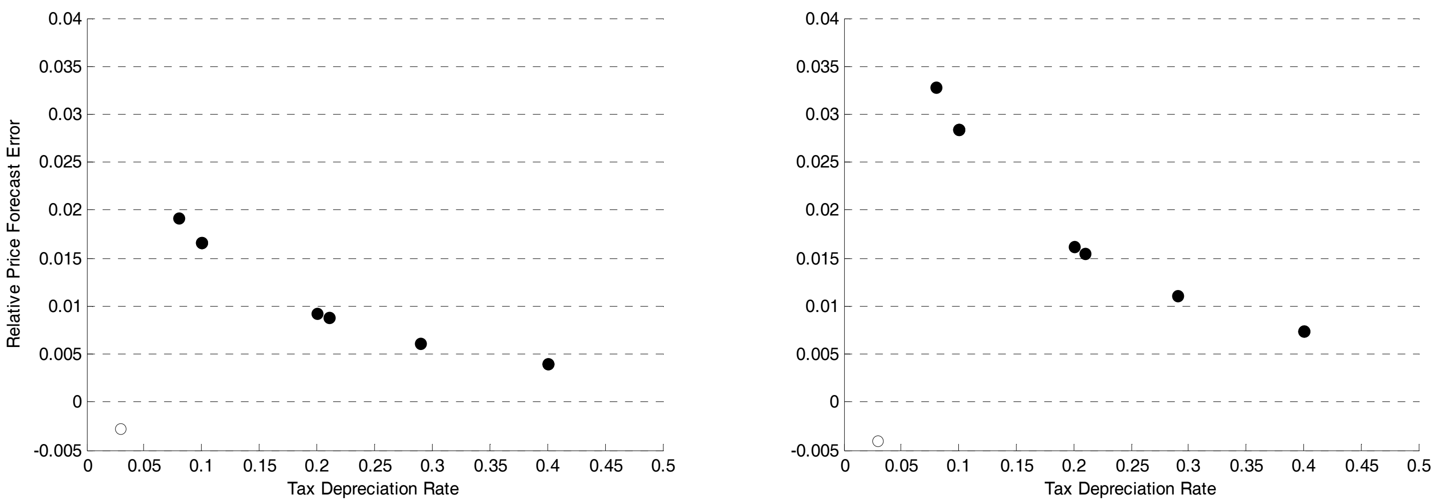


Figure 2: Simulated Forecast Errors from Bonus Depreciation Policy

A: Investment Quantities

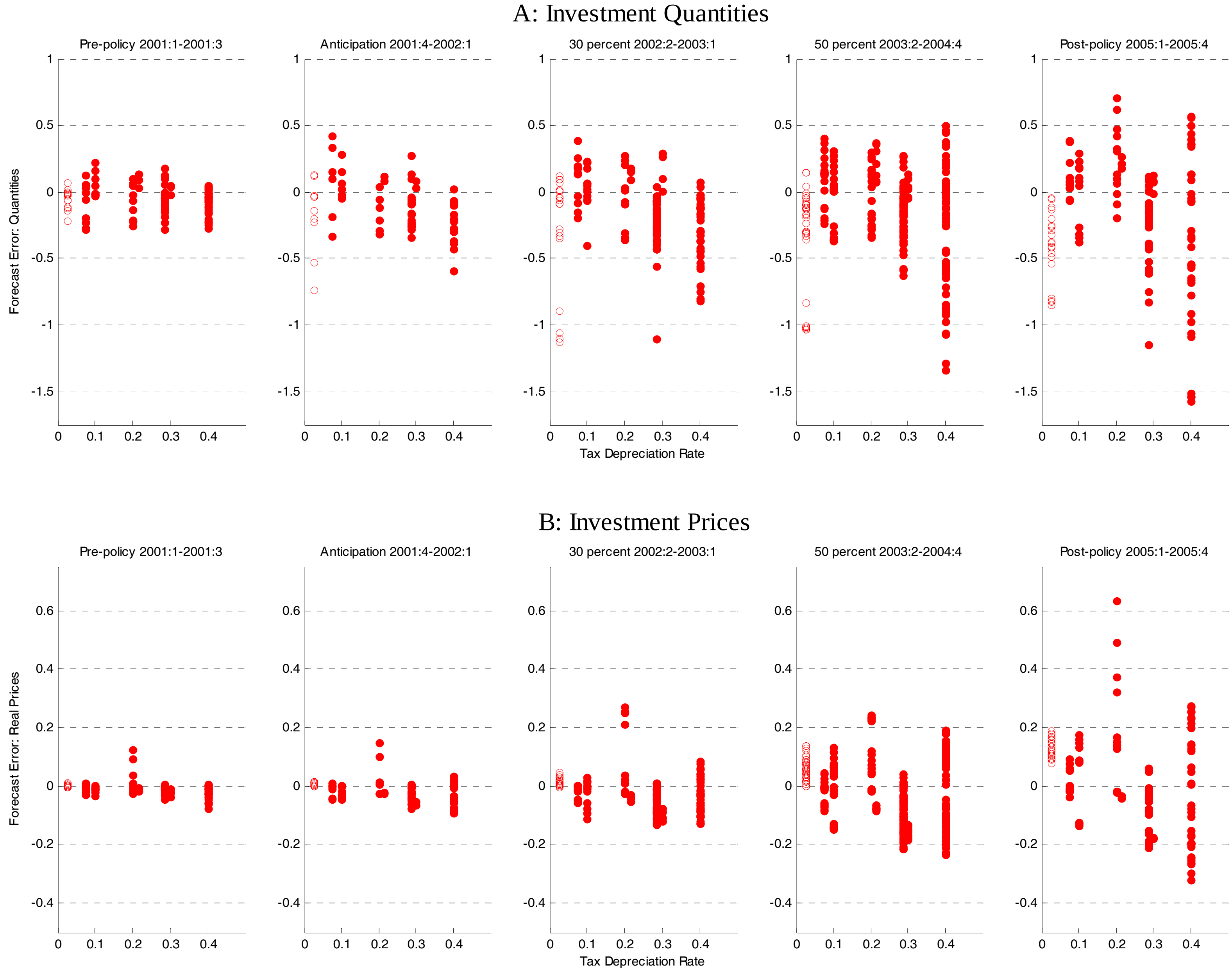


B: Investment Prices



Note: Simulated response of investment (top panels) and shadow prices (lower panels) for various types of capital to the 30 percent (2002:2) and 50 percent (2003:3) bonus depreciation policy. The tax depreciation rate ($\hat{\delta}$) is on the horizontal axis. Percent deviation from steady state is on the vertical axis. Each circle corresponds to approximate response to bonus depreciation based on equations (22) and (23). Solid circles are for capital that qualifies for bonus depreciation. Empty circles represent unqualified capital. In panel A, $\xi = 15$.

FIGURE 3: FORECAST ERRORS FOR REAL INVESTMENT AND REAL PRICES

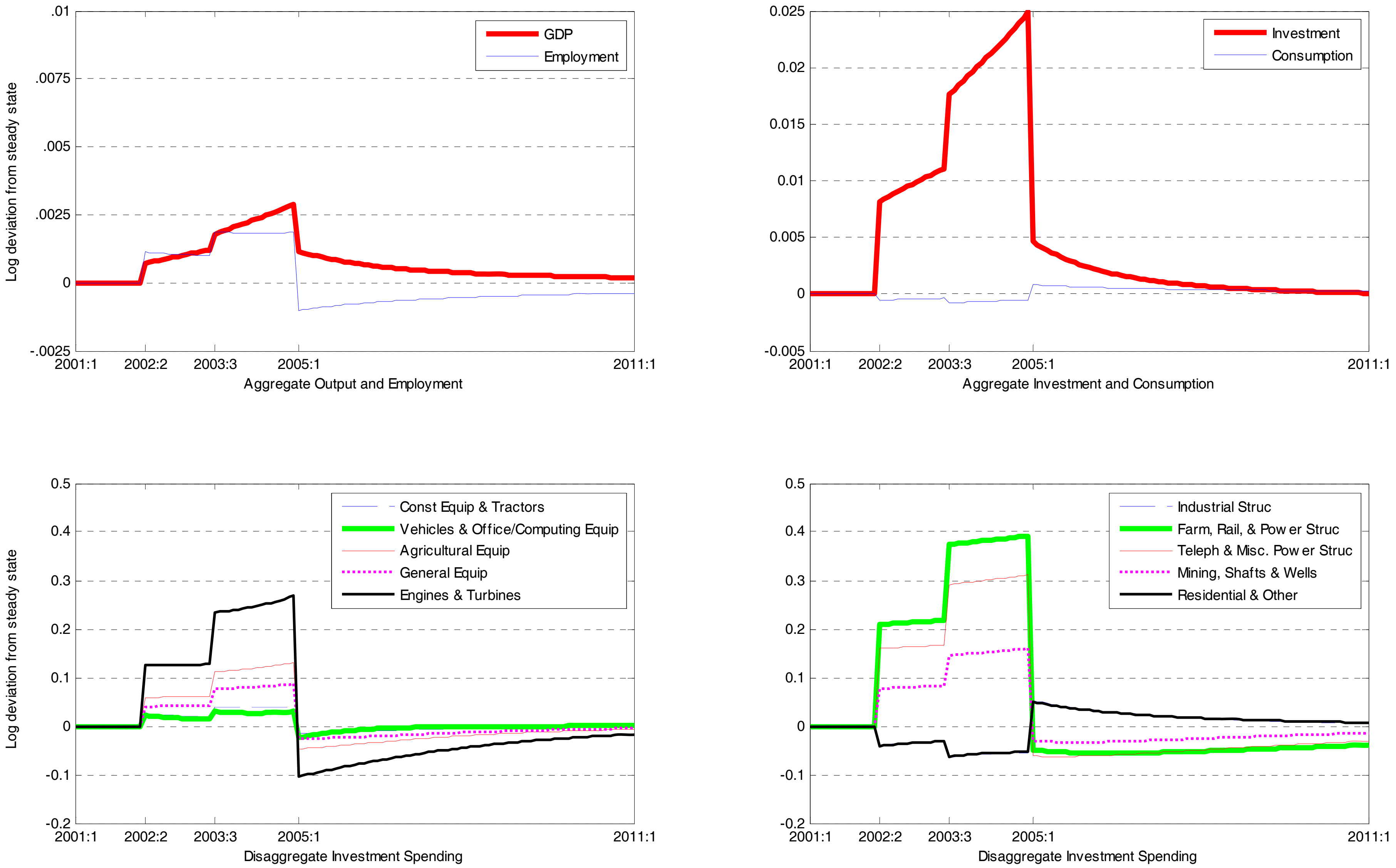


Note: The figure plots forecast errors for real investment (upper panels) and real investment prices (lower panels) by type of capital. The forecast errors come from the baseline forecasting equations (24) and (25). Solid circles are types that qualify for bonus depreciation. Empty circles are unqualified types. The tax depreciation rate ($\hat{\delta}$) is on the horizontal axis.

FIGURE 4: TIME-SERIES ESTIMATES OF THE BONUS DEPRECIATION RATE

Note: The figures plot the implied time path of the best fitting bonus depreciation rate (λ_t) for the investment data in equation (30). The top panel controls for aggregate effects with $\Psi_2^m \tilde{C}_t$ while the bottom panel estimates a time-varying marginal utility term (a time dummy) which is then scaled across investment types by the tax term Ψ_2^m described in the text.

FIGURE 5: SIMULATED AGGREGATE RESPONSE TO BONUS DEPRECIATION.



Note: The figures give the simulated reactions of the model in Section II to the bonus depreciation provisions of the 2002 and 2003 laws. See Tables 5 and 6 for the parameters underlying the simulation.